ProPath – A Guideline Based Software for the Implementation into the Medical Environment

General Overview about Guideline based Medical Information or Expert Systems and their Relation to Clinical Pathways

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Over the last decades, the amount of medical information has been growing rapidly. Online platforms such as patient’s and doctor’s blogs and forums and medical databases are widely and easily accessible to medical professionals as well as to the public. However, researching, filtering and evaluating the quality of this often overwhelming amount of data remains a challenge. Moreover, existing guidelines in the medical context are extensive and hardly applicable in the clinical context since reading and translation into clinical practice is time consuming [1][2]. Due to growing critical awareness among patients towards their medical treatment, there is an increased demand from internists, general practitioners, and other specialists, to explain medical conditions, treatment options and procedures in a more comprehensive fashion. In addition this discussion should be supported by the current state of clinical research. Expert systems could provide valuable support to fulfill these needs. Initial prototypes of expert systems in the inpatient arena were already implemented in the 1960’s in the context of clinical trials [3]. The main goal of these systems was to improve medical care by assisting in the medical decision process. However, most of these systems did not remain in clinical practice for a prolonged period of time. In most cases, the user interface of the software was too complex for daily use. Appropriate application and a detailed insight into these systems requires a lot of handbook knowledge. Therefore the initial hurdles for the integration of software into specific clinical application, faced by the potential users were too cumbersome. The main purpose of the project ProPath was to eliminate these issues and at the same time provide optimal clinical practice for the health care system in a variety of medical topics. Both in the outpatient and inpatient scenario, there is an increasing demand to support communication and to improve the distribution of published knowledge and the application of practical experiences within the medical field. The main challenge to achieve that objective is to design an intuitive, user friendly software product that can be integrated into the current standard network environments. An example of successful implementation of a medical information system into clinical practice is the PROP system [4]. It is a medical decision support system, which has been designed, developed and implemented in Austria in the course of Reformpoolsprojekt, in order to optimize the preoperative process. Since 2008, it is applied by general practitioners, pediatricians, clinicians and internists, in the state of Salzburg and was externally evaluated by the Paracelsus Medical University (PMU) in Salzburg. This paper provides an overview on how acquired knowledge can be utilized to reduce the complexity of designing and implementing clinical pathways (ProPath), supported by medical information or expert systems. Finally, statistical results evaluating PROP user-behavior are described.

Medical Information/Expert Systems; Clinical Pathways

1. INTRODUCTION AND MOTIVATION

Integration of Information and Communication Technology (ICT) Systems into a common network environment can improve medical care. A lot of research has been done investigating the clinical application of decision support systems and several successful projects have been implemented within hospitals as well as in the outpatient scenario [5]. One of the most important objective of this project was to increase efficiency of routine workflows in doctor’s offices and hospitals by means of providing for more standardized processes. When interacting with decisions regarding the treatment of patient’s compliance, their rights (persisting autonomy) of them have to be treated carefully. Especially when dealing with patients in a clinical scenario a software system must not replace a professionals’ expertise. Therfore the main aim of such applications is to support specialists in making reliable decisions based on the state-of-the-art knowledge. Since medical knowledge aquired from the literature on the one hand side (evidence), and experience collected in professional practice (expert opinion) on the other
hand are directly related to each other, a careful balance between these two needs has to be found when applying a decision support system. Because of the fact, that most medical scientists are specialized in a certain area of medical knowledge, software systems have to be very flexible related to context and in the presentation of the gathered data and information respectively. As the quality of the doctor-patient relationship is fundamental in establishing medical care, it presumably can never be replaced by a simple computer software. Some of the main intentions of using ICT in health care are to educate involved or interested individuals about the following:

- Current state of clinical research gathered from high impact journal publications representing high quality guidelines
- Interdisciplinary exchange of knowledge between inpatient and outpatient facilities, providing expertise in clinical case experience and studies

Moreover, user-friendly IT systems can support and positively affect the quality of care in hospitals and outpatient practices and at the same time affect working conditions [6][7].

**MEDICAL INFORMATION SYSTEMS**

In the 1990’s, various studies in different medical areas were pursued to improve the quality of care by using electronic medical information systems or medical expert systems respectively. All of these software programs comprised the management of a certain specific disease. At that time, the necessity of the current state of research and the need of optimizations of procedures and of medical quality raised the motivation to invent, introduce and finally facilitate such systems within the health care sector. One of the pioneers in using IT systems supporting medical procedures was Edward H. Shortliffe, from Stanford California. Starting in the late 80’s, he started to use artificial intelligence in medicine by interpreting and adapting successful applications from the mathematical and chemistry sector. By doing this, the development of the first medical expert systems like MYCIN (the name is related to the bacterium Actinomycetes [3]) a software for infectious disease specialists, PIP (present illness program [8]) an application for the guidance of the disease process, INTERNIST-1 (a synonym for specialists in internal medicine [9]), a system for general medical medicine and CASNET (causal-associational network [10]), an application for ophthalmologists dealing with the cure of glaucoma became possible. Nonetheless, the implementation and a usage in the clinical routine has not been achieved. Due to limitations, such as a lack of data interpretation made it impossible to find solutions for complex medical problems. One approach to deal with this issue was to improve the visual representation of the data. This method of resolution was adapted by ONCOCIN (oncology [11]), treatment. It has to be mentioned that all of the systems pointed out above are based on underlying „if-then-else“ statements. Using these statements the systems build rules to group symptoms. Thereby most of the rules are split up into four kinds of clauses. They are of either “definitional”, “cause-to-effect”, “effect-to-cause” or “associational” nature [3].

**A. General Studies about Medical Expert Systems**

Probabilistic methods have often been used to prove the reliability of the rules mentioned above [12]. PRIMEROSE (probabilistic rules based on rough set theory [12]) is a software application, generating rules for expert systems. When using these tools it is important to double check the generated results with data from real world diagnoses by experienced medical experts. RHINOS (rule-based headache and facial pain information organizing system [13]) a decision support system dealing with headache or facial pain was used to find the appropriate rules. Comparisons to the learning methods AQ15 (heuristic algorithm from A to Q), CART (Classification and Regression Trees), and ID3 (Iterative Dichotomiser) conclude that the PRIMEROSE rules showed a better performance. To perform the experimental pattern recognition and information retrieval methods were implemented [12]. Another medical expert system was CHD (Coronary Heart Disease [14]) used for coronary heart disease evaluating the rate of mortality/morbidity. Similar to the system described above, it relies on probabilistic algorithms and its objective was to find strategies for risk-factor interventions. The system can only be used within clinical studies. The knowledge representation is based on “if-then”, “condition-action” or “situation-action” concepts. As a result it was shown, that independently from the conclusions generated by CHD, clinical experts would define the same diagnoses as this expert system [14]. The XNEOr (expert system for neuro-oncology [15]) system used for brain tumor therapy was tested to optimize the comprehensive process for the treatment of pediatric brain tumors. Brain tumor surgery requires a large team of medical experts. Supporting the knowledge and management of such a large team was the motivation for using computer systems. The main idea was to interface on a database management system. However, the study showed, that database management systems are not flexible enough to handle complex brain tumor cases. Therefor, it would be necessary to gather an electronic decision system which adjusting to variable circumstances and present the different solutions [12][15]. Further information systems are Dxplain, Isabel, Llidi, MDX, Diagnosis Pro and MD, PETS, Care, DIAGNO II, GIAG, CADENZA, TRIMIS, CADIAG-2, Medinfo, TMIS, PROMIS, EMCIN, MICROPUFF, PUFF/MED, COSTAR, Expert Ease, LOOPS, OPS5 [17][18].

**B. Clinical Pathways**

A clinical pathway is a criterion-oriented medical process including diagnosis, therapy and comprehensive medical care. A clinical expert is guided through parts or the whole process of medical care by predefined steps based on the symptoms and the collected data of the patient. Pathways build a decision tree, where each step is set by a precondition (e.g. medical history) and supports the medical expert in decision making. Clinical pathways generating a change in organizing clinical work should be supported by evidence based guidelines [19].

For example, in a current study confirmed the positive impact of esophageal cancer therapy by using „standardized oesophagectomy clinical pathway“ (SOCP). The postoperative results are positively influenced by medical propositions of the system [20]. There are several different approaches how
clinical pathways are formed. In another study stochastic process algebra is used to select data from public clinical databases. It was shown that unnecessary pathways could be eliminated. This algorithm shows to safe time and costs by limiting the amount of days stayed. An additional study describes the use of process mining techniques to define which medical behavior is required and how it is positioned in a flowchart. The evaluation was done with real data of a hospital in China and showed similar results as the study described above [21][22].

All of these studies were performed solely within hospitals and were never used in the outpatient scenario. At the time of publication of this paper and to the best of our knowledge none of the developed applications are currently being used.

II. PROP – AN APPLICATION FOR PREOPERATIVE TESTING

In contrast to the described systems, which were only intended for and used within an inpatient scenario, PROP is an example where an electronically supported clinical pathway was introduced in both, the outpatient and the inpatient setting. In light of to the implementation of the PROP system the current project was initiated. The study showed positive effects in both scenarios, as well as in the quality of care represented by guideline-adherence and economical factors. As a result of these findings, a software prototype for a medical information system has been developed within the framework of the Austrian Reformpoolprojekt in 2008 [23][24][25].

PROP was implemented in order to explore and prevent the duplications of medical examinations and prevent unnecessary examinations, which may easily occur in the preoperative evaluation process and also to support the guideline adherence. A communication gap between inpatient and outpatient medical professionals was identified as one of the reasons for the first problem. The second problem can be prevented by reviewing the past medical history and procedural information to translate medical information into a testing proposal for each individual patient [26]. Therefore the Austrian Society of Anesthesiology, Resuscitation and Intensive Care Medicine (“ÖGARIT” [24]) [23][24] has defined guidelines providing for standardization and harmonization of the preoperative patient evaluation for the internal departments in anesthesiology and for outpatient institutions. The guidelines are (re-)defined and adapted on a yearly basis. As part of the project PROP, the idea has been to incorporate these guidelines into an online decision support software system. The software, also named PROP, is a database based “self-explanatory” platform enabling users, e.g. doctors, to insert patient- and process-related information in order to receive a standardized proposal for the preoperative assessment. This online “questionnaire” contains questions about the patients’ health condition which is displayed within 32 parameters subdivided into 14 categories (type of surgical procedure, ASA-Classifications, lung, metabolism, liver, kidney, coagulation, neurology, oncology, gynecology, drugs, dyspnea, hematology, heart) and represent the Patient-Anamnesis-Matrix. Following the completion of the questionnaire the user receives a list of necessary examinations for in order to complete a comprehensive preoperative assessment process in a standardized and optimized fashion [5].

According to these main characteristics, the PROP system, can improve patient care by:

- Standardizing and optimizing the preoperative processes
- Improvement of patient satisfaction and economical factors by reducing the quantity of tests
- More efficient utilization of resources available in a hospital setting by using outpatient infrastructures
- Optimizing preoperative procedures: shorter ways for patients, reducing physical and mental stress in geriatric and pediatric patients
- Generating data on preoperative care and documentation of the process in order to provide for improvements in medical care

Within the PROP Project the Salzburg University of Applied Sciences (http://www.fh-salzburg.ac.at) was appointed with the development of the necessary software for the medical information system. This has been done in close cooperation with medical experts in the field of anesthesiology (Gerhard Fritsch MD, Department of Anesthesiology, Perioperative Medicine and Intensive Care, Paracelsus Medical University Salzburg, Austria). Throughout the project and since then many different analyses have been conducted based on the data, collected by the PROP prototype [4][27][28]. The data collected from these studies was moreover analyzed to study users. A description of the results can be found in chapter V of this paper.

III. PROPATH – CLINICAL PATHWAYS IN MEDICAL INFORMATION/EXPERT SYSTEMS INCLUDING FEEDBACK/EVALUATION

PROP represents a successful example on how decision support systems can efficiently support medical processes. The current version of the software PROP gives a chance to widen the existing system with regards to revised decision support systems including Artificial Intelligence, named medical expert systems. This extension requires detailed studies on how the system could collect and score publications within relevant medical databases, like Pubmed – Medline. Therefore, it is necessary to develop or adapt a software algorithm which could handle the given parameters, like the type of treatment, age, sex, cardiac risk factors etc. and find appropriate sources. Finally, the advised results should support the expertise of medical scientists. Afterwards, a further study should concentrate on the evaluation of the output generated from this expert system and compare its results with the conclusions of a human expert. Both steps are planned to be done within a project named ProPath.

With ProPath, a new generation of medical processing will be implemented. Clinical pathways will be used in the decision process for optimizing medical treatments in a hospital as well as in the outpatient setting. The new idea is to integrate clinical pathways into expert systems. These should be built in a very dynamic way, to be applicable for many different types of clinical processes. For this reason, an expert system has to be
observed from the perspective of a doctor, nurse, administrator or patient. The main purpose is to elaborate a software tool, which is intuitive, easy to handle and very effective in order to increase the quality of care in the medical environment. It will be based on the needs of all parties involved to make the system attractive for the integration in existing software networks as well as in the clinical routine and in Hospital Information Systems (HIS [16]) as in practices. An additional factor in the research within the ProPath system is to further evaluate the current communication gap between the inpatient and outpatient setting and then closed with the help of ICTs.

Another objective of ProPath is to include the development of an automatic feedback evaluation tool into the expert system. Clinical Pathways are implemented within medical expert systems including an integrated feedback evaluation. One reason that until now only a few systems are being used in hospitals, are poorly conveyed systems and the generation of non-optimal treatment advice. Therefore, it would be helpful to get feedback from long-term users of these systems. Working with fragmentary software could cause frustration and bad perception by the user. To be able to understand how this evaluation can be implemented in an appropriate way, personalized feedback conversation with medical experts who have been using PROP, have already been done. After finalizing these evaluations a prototype for the diagnosis of “backache”, where the treatment is guideline based in Germany [25] is generated and tested in at least to practices for a period of 6 months. Within this new platform based on the PROP system, “gender medical” aspects will also be included.

IV. EMPIRICAL ANALYSIS OF PROP-DATA

In this section empirical results of user-behavior within the PROP system between 1st October 2009 and 30th September 2011 are being described. During this period in the state of Salzburg about 400 inpatient and outpatient users were authorized to apply this medical information system in order to support the preoperative process [5]. For a total number of 19 797 patients the preoperative evaluation using PROP has been carried out. The statistical analyses were evaluated with IBM SPSS Statistics 19.

In Table I the quarterly periods of each year and its absolute and relative frequencies of the number of PROP applications are presented. Table II shows the number of outpatient and inpatient treatments with PROP over two years.

<table>
<thead>
<tr>
<th>Quarterly Division</th>
<th>Year</th>
<th>Period</th>
<th>Absolute Freq.</th>
<th>Relative Freq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Oct. – 31st Dec.</td>
<td>09</td>
<td>Q1_4</td>
<td>3,508</td>
<td>17.7%</td>
</tr>
<tr>
<td>1st Jan. – 31st Mar.</td>
<td>10</td>
<td>Q2_1</td>
<td>3,013</td>
<td>15.2%</td>
</tr>
<tr>
<td>1st Apr. – 30th Jun.</td>
<td>10</td>
<td>Q2_2</td>
<td>1,993</td>
<td>10.1%</td>
</tr>
<tr>
<td>1st Jul. – 30th Sep.</td>
<td>10</td>
<td>Q2_3</td>
<td>1,817</td>
<td>9.2%</td>
</tr>
<tr>
<td>1st Oct. – 31st Dec.</td>
<td>10</td>
<td>Q2_4</td>
<td>1,992</td>
<td>10.1%</td>
</tr>
<tr>
<td>1st Jan. – 31st Mar.</td>
<td>11</td>
<td>Q3_1</td>
<td>3,054</td>
<td>15.4%</td>
</tr>
<tr>
<td>1st Apr. – 31st Jun.</td>
<td>11</td>
<td>Q3_2</td>
<td>2,162</td>
<td>10.9%</td>
</tr>
<tr>
<td>1st Jul. – 30th Sep.</td>
<td>11</td>
<td>Q3_3</td>
<td>2,258</td>
<td>11.4%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>19,797</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

The completion time in minutes defines the time between the login of the user and the activation of the finalization button in the PROP system upon where the preoperative evaluation process is completed. More details about the usage of the software are given in [5]. As demonstrated in Fig. 1, during the first five quarterly periods the completion time average decreased especially in the inpatient setting. In the quarters four and five (Q2_3, Q2_4) the results stabilized below 5 minutes in both settings. After that period in Q3_1 is a difference of over 30 minutes of the average occurred in the inpatient setting. After that the completion time decreased again from about 15 minutes in Q3_2 to below 10 minutes.

![Bar chart on the mean finalization time of preoperative tests completed with the application PROP in the state of Salzburg. The results are provided for inhospital and outpatient users over a period of two years devided into quarters.](image)

One reason for the increased numeric value in Q3_1 is that in the hospital of Salzburg a higher recognition rate in the medical department where PROP was used, was observed. After this period new staff was employed and got used to the system. In addition to this, the access to the system was not always immediately followed by a completion as there was an essential difference in the work-flow between the inpatient and the outpatient setting. As a result, new staff was employed and got familiar to the system. Evaluation of this graph indicates a learning curve of the users, suggesting user-friendliness of the software.
V. SUMMARY AND FUTURE PERSPECTIVE

Medical expert systems are used to collect a large volume of data and ensure quality of care in the health care. To the best knowledge of the authors no high quality studies dealing with clinical pathways were published until to date. ProPath’s purpose is to implement a guideline based medical expert system including feedback evaluation. Because of the proposed dynamic implementation of the underlying data, every type of medical knowledge matrix could be integrated in the proposed system. It will be necessary to test the system and expand upon Artificial Intelligence to augment the existing medical decision support system in order to turn it into a medical expert system. This enhancement is required to allow the system to dynamically distinguish the quality of good and bad sources and, in addition, to be flexible in respect to different medical subspecialties. A significant amount of know-how has been generated over the years already in regards to research, implementation and development. Based on that high potential of knowledge and after considering further intensive state-of-the-art analysis, the continuation of research in clinical pathways and the implementation of expert systems is supported. The goal is to transform data to information applicable for an advanced expert system. As mentioned above this goal moreover includes the development of algorithms from artificial intelligence. We are planning standardize the methods included in the final version of ProPath, making the system capable of implementing most of the existing clinical pathways.

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