Introduction

Pressures on quality, time and financial resources in the health care system have resulted in the need to organize medical processes more efficiently. It should always be remembered that financial and organizational improvements cannot reduce treatment quality. One of the attempts to maximize quality and cost efficiency is the introduction of clinical pathways.

Clinical pathways (also known as Integrated Care Pathways [Campbell, Hotchkiss, Bradshaw & Porteous, 1998], CaseMaps [Bollmann & Beck, 2002] or Critical Pathways [Pearson, Goulart-Fischer & Lee, 1995]) are documents which describe the activities involved in the treatment of patient groups with specific diagnoses or conditions. These documents are created by interdisciplinary teams of professionals based on evidence found in medical standards and verified scientific publications. In contrast to general clinical guidelines, clinical pathways are constructed with the consideration of conditions and resources of local health care institutions. The activities determined by clinical pathways involve all the professional groups in a hospital (not only the physicians but also the nursing and technical staff). The standardization process reduces variations in clinical processes, which are often the source of errors [Panella, Marchisio & Di Stanislao, 2003]. Pathways may decrease the patient’s length of stay in the hospital, and reduce complications and costs [Weiland, 1997]. The transparency of treatments carried out according to clinical pathways has the potential to improve the quality of medical processes, for example redundant activities can now be easily detected and eliminated. The use of clinical pathways can reduce medical documentation time by only recording deviations from the pathway (“charting by exception”) [Pearson et al., 1995] [Roeder & Küttner, 2006]. Clinical pathways are an invaluable source of information about hospital procedures. Their construction can integrate fragmented knowledge from different divisions of health care institutions. If regularly updated, they can provide medical staff with current, evidence-based data on hospital procedures.

The publication of clinical pathways can help professionals to better understand their roles and responsibilities [Panella et al., 2003]. Pathways have the potential to improve cohesion in teams by clarifying relationships between different medical staff groups (physicians, nurses and technicians). Furthermore, pathways can assist new employees greatly by introducing
them to the details of hospital procedures. Since clinical pathways are financially optimized they are an effective method for teaching students about cost-effective practice.

A potential risk of using clinical pathways for educational purposes cited by many authors is that they undermine training by discouraging experimentation, and stifle innovation and independent thinking [Woolf, Grol, Hutchinson, Eccles & Grimshaw, 1999][Campbell et al., 1998][Pearson et al., 1995]. Some physicians fear that physicians trained on clinical pathways will not be capable of treating patients autonomously. However, it should be noted that clinical pathways are constructed only for the most common and well known procedures, therefore physicians will still have to deal with rare cases independently. In addition, it is still necessary to select the correct pathway and react immediately in a situation where the treatment results do not fit the values anticipated by the standard.

Clinical pathways which are specially adapted for lay readers can be used to inform patients about forthcoming medical activities. They can answer the most frequent questions which arise during each treatment phase. Derived from guidelines, clinical pathways may be used to present the pros and cons of treatments and empower patients to make better informed health care choices [Woolf et al., 1999]. They have the potential to build better relationship between patients and physicians.

Materials and methods

The legacy system

The >>mipp> project has been started at the Aarau Canton Hospital (Switzerland) in 1995 [Holler, Schmid, Müller, Reemts, Bissat & Rieben, 2002] [Rieben, Müller, Holler & Ruffin, 2003]. In 2005 118 clinical pathways were implemented and deployed in the hospital (22 in general medicine, 77 surgery, 12 gynaecology, 7 paediatrics) amounting to more than 40% of all inpatient treatments [Canton Hospital Aarau, 2005]. Clinical pathways are currently used in Aarau to account for procedures which are funded by health care insurance.

Clinical pathways in >>mipp> project are comprised of components. These components consist of descriptions of activities executed within a single medical service by members of particular staff groups (physicians, treatment and nursing staff, and others). Not all activities are mandatory as some of them carry a probability value which indicates the frequency of occurrence of this activity. Each activity also carries a cost value and a cost centre. Many of those activities have their origins in standard activity catalogues (e.g. TARMED [TARMED Suisse, n.d] in Switzerland) or the hospital’s internal activity catalogue. Besides these activities components also contain other properties such as quality requirements, time specifications and general descriptions. All components from a path are depicted as a flowchart.

>>mipp> clinical pathways were created using general purpose tools. The >>mipp> pathways were stored in a Microsoft Access database and were visualized by flowcharts created using Microsoft Visio or Power Point. A Microsoft Access application was implemented to utilize and modify the data. Clinical pathways were published on the hospital’s intranet as Access reports in PDF format.

Extension of the >>mipp> system

The clinical pathways developed within the >>mipp> project have proven to be very useful in the hospital, however, there are certain aspects which need to be refined or extended. The pathways contain mainly financial data as they were created for billing and costs transparency purposes, therefore only little advantage has been taken of their educational potential. The >>mipp> flowcharts are not uniform because they were created with general purpose tools by different authors, and the links between components are stored only in graphical form; not as relations in the database. This prohibits the possibility of integrating the pathways automatically into the workflow of the hospital information system1. The existing flowcharts are difficult to modify and changes made to the flowcharts do not automatically modify the database. Additionally, Microsoft Access which was used for storing pathways’ data, is in our opinion not well suited to work in web environment.

The objective of the proposed tool is to maximize the educational potential of the >>mipp> project. The knowledge stored in pathways should be presented in a more accessible and interactive form. Therefore, the extension is expected to provide different views on the data depending on the target audience (medical staff, patients) and the intention of user (e.g. staff group oriented, flowchart oriented). Additionally, a function is required which includes external knowledge sources (e.g. EBM publications, e-learning sites) in the pathway description. It was decided that the extension of the >>mipp> project should not modify the legacy database schema or the >>mipp> Access application. The new system should be flexible enough to support further extensions (e.g. integration with the new hospital information system that will be implemented in the near future) and to function also outside the hospital in Aarau.

Implementation

To fulfill the requirement for flexibility we have decided to use XML to store and transfer data. In fig.1 we present the overall architecture of the system after extension. We developed a new graphical editor called ‘BIT Pathways’ to create and modify new pathways. The editor is a Java Swing application. The choice of Java technology has the advantage of not restricting the application’s usage to any particular operating system. We have not decided to develop BIT Pathways entirely as a web application due to the complexity of the flowchart editor, which is still very difficult to implement efficiently in a generic web browser. Legacy data is imported from the >>mipp> data- base (JDBC-ODBC bridge) using a web service (Axis WS implementation). Clinical pathways can be stored locally as files or remotely in a native XML database (eXist [Meier, 2003] accessed using the XML:DB interface). Users can view selected pathways with a JavaScript-enabled web browser. The data in the XML database is accessed by XQuery scripts, translated into HTML using XSLT. Sections of the pathways (e.g. component properties) can be downloaded asynchronously using

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1 For integration of clinical pathways and guidelines into clinical workflow refer to the SAGE model [Campbell, Tu, Boyer & Mansfield, 2003] [Tu, Shankara, Campbell, Hrabak, McClayb & Huffc, et al., 2004] or other approaches e.g. [Dazzi, Fassino, Saracco, Quaglini & Stefanelli, 1997].
AJAX (Asynchronous JavaScript and XML) technology [Crane, Pascarello & Darren, 2006], which provides better performance for the user interface.

The clinical pathways created in the extended mipp system are stored locally as XML files or remotely on an XML database server (authentication and authorization functions were implemented). We chose to use a native XML database server rather than an XML enabled RDBMS because the conversion overhead caused by the properties of the stored data would nullify the superior performance of a relational database. A native XML database which accesses the data without conversion is very advantageous when processing large quantities of XML data [Fong, Wong & Fong, 2003]. We selected eXist as the native XML database server implementation because it is stable, open source, and it supports XQuery processing. In addition to the XML data model – for efficiency reasons – an automatically generated graphical file of the flowchart (in PNG format) is also stored in the database.

Several proposed specifications for encoding clinical guidelines already exist. Among them are e.g. Arden Syntax, GLIF [Ohno-Machado, Gennari, Murphy, Jain, Tu & Oliver, 1998], GEM [Shiffman, Agrawal, Deshpande & Gershkovich, 2001] [Georg, Séroursi & Bouaud, 2005] and CPG-RA [CPG-RA, n.d]. Our goal of designing pathways, which can be used as educational resources has lead our research towards narrative guidelines (like GEM or CPG-RA) rather than methods which

**Tab. 1. Summary of an exemplary attributes template created for teaching purposes**

<table>
<thead>
<tr>
<th><strong>Whole pathway properties</strong></th>
<th><strong>Attributes</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attrib Group</strong></td>
<td></td>
</tr>
<tr>
<td>General properties</td>
<td>Id:string, Name:string, Diagnosis codes:icd[], Procedure codes:icd[], Pathway description:html, Authors:string[]</td>
</tr>
<tr>
<td>Sources</td>
<td>National sources:ref[], International sources:ref[], Web sources:url[]</td>
</tr>
<tr>
<td>Patient</td>
<td>Patient – Path description:html, Lay Link:url[]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Pathway component properties</strong></th>
<th><strong>Attributes</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attrib Group</strong></td>
<td></td>
</tr>
<tr>
<td>General properties</td>
<td>Name:string, Phase:enum, Category:enum, Description:html, Risk factors:html, Duration:time</td>
</tr>
<tr>
<td>Activities</td>
<td>Activities:activity[]</td>
</tr>
<tr>
<td>Sources</td>
<td>National sources:ref[], International sources:ref[], Web sources:url[]</td>
</tr>
<tr>
<td>Drugs</td>
<td>Drugs:drug[]</td>
</tr>
<tr>
<td>Patient</td>
<td>Patient – Path description:html, Lay Link:url[]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Pathway branch properties</strong></th>
<th><strong>Attributes</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attrib Group</strong></td>
<td></td>
</tr>
<tr>
<td>General properties</td>
<td>Name:string, Description:html</td>
</tr>
<tr>
<td>Sources</td>
<td>National sources:ref[], International sources:ref[], Web sources:url[]</td>
</tr>
<tr>
<td>Patient</td>
<td>Decision rational:html, Lay Link:url[]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Pathway edge properties</strong></th>
<th><strong>Attributes</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attrib Group</strong></td>
<td></td>
</tr>
<tr>
<td>General properties</td>
<td>Description:html, Probability:double</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Start element properties</strong></th>
<th><strong>Attributes</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attrib Group</strong></td>
<td></td>
</tr>
<tr>
<td>General properties</td>
<td></td>
</tr>
<tr>
<td><strong>End element properties</strong></td>
<td><strong>Attributes</strong></td>
</tr>
<tr>
<td><strong>Attrib Group</strong></td>
<td></td>
</tr>
<tr>
<td>General properties</td>
<td>End premises:html, Recommendations:html</td>
</tr>
</tbody>
</table>
specify executable code (Arden Syntax, GLIF). However, our goal is also to preserve maximal flexibility for the teachers in reaching their educational goals. This reason leads us to the opinion that the mapping of the current structure into an established standard is, for the time being, impractical. We have decided to create our own XML schema which is very easily modifiable and which may, if needed, be mapped to an exchangeable format like GEM.

We have decided to divide our XML documents into 3 parts:
- Header – containing general attributes describing the whole pathway (e.g. the pathway name or detailed characteristics of patients which fit into the pathway, information about authors of the pathway, and multiple choice-questions about the pathway).
- Elements – containing properties of all workflow elements. Including properties describing the graphical position of the element in the diagram, and the purpose of the element.
- Connections – this section contains relations between flowchart elements.

Elements are characterized by their class. We distinguish start elements, end elements, components (corresponding to the major task steps of the described procedure), branches and edges (connections). There is also a class that represents the whole pathway. Each class has its own attribute set distributed among one or more attribute groups. For instance, elements of the class ‘component’ contain attribute groups: general properties; activities; sources, drugs, patients. The attribute group ‘sources’ contains attributes which contain literature references for medical staff willing to extend their knowledge about the given step of the pathway. Attributes may consist of a single value or a list of values. Values have types – beside standard data types (string, boolean and numerical values) we have specified more complex types such as activity, classification code, person, multiple-choice-question and enum. Type ‘enum’ means a value from a controlled set of terms.

The list of available attributes and attribute groups is defined by templates in XML format and may be changed easily. This feature allows the usage of BIT Pathways in various institutions and for diverse purposes. Tab. 1 presents a summary of an exemplary template created for the use in teaching of clinical pathways. Presented are attributes for all classes of elements. Each attribute (in bold) is additionally characterized by its type. Types ending with [] denote list of attributes of the same type.

**Results**

A learning process based on clinical pathways involves, in our opinion, two main groups of users:
- medical educators – i.e. those preparing learning materials regarding pathways
- learners – i.e. those interested in gaining knowledge about topics covered by pathways. Members of this user group can be medical professionals (physicians, nursing staff, and technicians), students or lay readers (patients or patient’s family members). The diversity of users in this group results in the requirement for medical educators to prepare differently profiled materials for the same component.

The task of medical educators is facilitated by the newly developed pathway editor called BIT Pathways (fig. 2). This editor (currently available in 3 language versions: English, German and Polish) assists the educator in developing new clinical pathways, adding educational materials to pathways and importing existing pathways or their elements from the legacy
system. The import process of pathways is enabled by a web service. The user can choose from more than 100 existing pathways and then select the components to import.

Clinical pathway flowcharts are displayed in the main panel of the application. The right-hand panel displays the attributes of the selected flowchart element. Attributes are displayed in read-only mode as an HTML page, or as an editable grid in edit mode. Attributes with complex types have their own editors activated by a double click on the attribute value row.

Activities can be imported from an integrated hospital activity catalogue browser ([TARMED] [TARMED Suisse, n.d] for Switzerland, and [Katalog/G285 Wiadczen/276 Szpitalnych NFZ] [Polish National Health Fund, n.d.] for Poland). The adaptation of a component’s content for different user groups is realised by two means. Firstly, by setting a value in the component’s category attribute according to the intended user group (e.g. physicians, treatment staff, nursing staff, etc). Secondly, by the use of attribute pairs in which one attribute contains data for medical staff members (students) and the other for lay readers (e.g. medical activity description/patient’s activity description, medical EBM link/patient’s educational link). The colour of a component in the graphical view indicates its assignment to a hospital staff group.

It is intended that learners will access information about pathways via the Internet or hospital’s intranet site using a web browser. Storing the data in an XML database makes it easy to provide different views of the same data for different user groups.

At present we provide three different views of clinical pathways: two for medical staff (students) and one for patients. The views for medical staff are flowchart and staff group view. For patients we provide general patient view.

The flowchart view (fig.3) displays the flowchart at the left-hand side of the window. When a component is clicked on its properties are asynchronously downloaded and displayed to the right of the diagram. Clicking on activities displays the general properties of the selected activity. The general patient view is similar to the flowchart view in that sense that it also displays a flowchart, however, clicking on a component displays information intended for patients. The flowchart view displays very detailed information written in a formal language, whereas the patient view presents general information about ongoing activities displayed in an easily comprehensible form for the lay reader.

We will illustrate this division using the Appendectomy pathway. The pathway’s global attributes define the inclusion and exclusion criteria of the pathway, and also give some links to EBM sources about appendectomy in general (pathogenesis, symptoms, diagnosis, differentiation, complications). The same attributes in the patient’s view explain some basic terms like appendix, (perforated/non-perforated) appendicitis or appendectomy. The post-operative component informs, for example, medical professionals about recommended means (drugs and their dosage), and patients about post-operative side effects (nausea, lethargy, dizziness, etc.) and, for instance, in the case of a perforated appendix, what a NG tube is and what is it used for. This approach could be extended in pediatrics by providing different materials for children of different ages and, in addition, materials for their parents (this feature is currently not supported).

The staff group view displays components ordered by different staff groups. This view is also called the ‘swimlane view’ because the data is arranged into columns. The first column contains all tasks to be done by physicians, the next contains activities for nursing staff, the next for technicians’, etc. The aim of this view is to compare the activities of different professional groups.
Pilot evaluation

The BIT Pathways system has been preliminary tested on an interdisciplinary group of 47 post-graduate students at the Jagiellonian University Medical College. Most of them graduated two years ago in medicine, pharmacy, physiology or health care management. All of them participated in a course on IT technologies in life sciences. Divided in groups of 2-4 persons course participants prepared in approx. one month time 14 pathways using the BIT Pathways editor. The pathways pertained topics from various medical disciplines including endocrinology(3 pathways), gastroenterology(2), infectious diseases(1), gastroenterology(3), genetic disorders(1), cardiology(2) and paediatrics(2). After presentation of the projects students were asked to take part in a short electronic survey concerning the applied course. Twenty six questionnaires have been returned (participation rate 55%). Seventeen students (65%) agreed (or strongly agreed) with the statement that BIT Pathways was useful in preparation of their clinical pathway (in a 1-5 Likert scale, 1 strongly disagree, 5 strongly agree, median = 4, mean = 3.76, SD = 0.88, one answer was not given). In a free text field students could point out problems related to usage of the program. Among the most frequent comments was the difficulty of inserting multimedia files (images, movies) into pathway’s description or the inability of selecting more than one pathway component. Some students wished to have more flowchart symbols available in the toolbar. Course participants were also inquired about their general opinion on clinical pathways. Nineteen students (73%) agreed (or strongly agreed) with the statement that clinical pathways have a chance to be accepted in Polish hospitals (Likert scale, median = 4, mean = 3.92, SD = 0.80 what proves the relevance of the touched on subject. Asked about the major benefits of clinical pathways, students pointed out introduction of evidence-based practice, improvement in personnel communication, improved hospital audit and effective teaching resource for novice employees. The major hindrances of introducing clinical pathways in Polish hospitals were in the student opinion the scepticism of the hospital’s managements and high costs of clinical pathways’ implementation.

Discussion

Analysis of the projects delivered within the course on clinical pathways proved once more that construction of clinical pathways is not easy and should be practiced. Improper usage of branching elements, too detailed modelling of clinical pathways fragments, difficulties in distinguishing between patient’s state and actions performed within the clinical pathway were the most common errors. Most of the course participants were also not aware (or unable to express) the tasks undertaken by other professional groups involved in the modelled medical process.

The conclusion based on the experience of Canton Hospital Aarau is that development of clinical pathways in general purpose tools like Microsoft Visio or Microsoft Power Point pose the threat of discrepancies in interpretation of clinical pathways even if they are developed in one single institution. This results in pathways incomparability and difficulties in implementing and updating them in hospital information systems. A good system for authoring and learning clinical pathways should be a trade-off between giving the practitioners/medical teachers free hand in expressing their knowledge and putting constraints to preserve uniformity of clinical pathways. Unfortunately, awareness of dedicated tools for pathway construction is not common knowledge. The BIT Pathways system attempts to fill that gap by offering a means of practising clinical pathways in academic settings. Being derived from an existing system imparts the tool with a certain degree of authenticity required for successful learning. The concept of templates setting up the list of permitted attributes makes the system suitable for many different purposes.

We believe that BIT Pathways have the potential to become a platform for learning about medical processes as well as acquiring skills of pathway construction. The pilot evaluation delivered many ideas for extending BIT Pathways by new features as e.g. the possibility of creating hidable subpathways or adding multimedia to the pathway description. More in-depth studies evaluating the educational outcomes are definitely needed and will be presented in the future.

Conclusions

Clinical pathways are a modern tool for ensuring quality and reducing costs and variations in health care. They rely upon evidence based documents and are tailored for a hospital’s individual needs, making them to an invaluable source of knowledge about hospital procedures. The process of creating, modifying and publishing clinical pathways is supported and improved by the IT methods outlined in this paper. The BIT Pathways system which we present here is an extension of the clinical pathway project and represents a method for ensuring easier access to clinical pathways for learning purposes. The system was implemented mainly using XML technologies, which gives it the potential to be easily integrated into any hospital’s IT infrastructure. Due to the choice of flexible technologies and a clear separation of different system components, selected modules can be used outside the Canton Hospital Aarau. The preliminary evaluation of BIT Pathways at the Jagiellonian University Medical College encourages in further development and evaluation of the system.

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BIT Pathways – a tool for teaching and learning clinical pathways


Web References

