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ORIGINAL ARTICLE

New methods for clinical pathways—Business Process Modeling Notation (BPMN) and Tangible Business Process Modeling (t.BPM)

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Abstract
Purpose Clinical pathways (CP) are nowadays used in numerous institutions, but their real impact is still a matter of debate. The optimal design of a clinical pathway remains unclear and is mainly determined by the expectations of the individual institution. The purpose of the here described pilot project was the development of two CP (colon and rectum carcinoma) according to Business Process Modeling Notation (BPMN) and Tangible Business Process Modeling (t.BPM).
Methods BPMN is an established standard for business process modelling in industry and economy. It is, in the broadest sense, a computer programme which enables the description and a relatively easy graphical imaging of complex processes. t.BPM is a modular construction system of the BPMN symbols which enables the creation of an outline or raw model, e.g. by placing the symbols on a spread-out paper sheet. The thus created outline can then be transferred to the computer and further modified as required. CP for the treatment of colon and rectal cancer have been developed with support of an external IT coach.
Results The pathway was developed in an interdisciplinary and interprofessional manner (55 man-days over 15 working days). During this time, necessary interviews with medical, nursing and administrative staffs were conducted as well. Both pathways were developed parallel. Subsequent analysis was focussed on feasibility, expenditure, clarity and suitability for daily clinical practice. The familiarization with BPMN was relatively quick and intuitive. The use of t.BPM enabled the pragmatic, effective and results-directed creation of outlines for the CP. The development of both CP was finished from the diagnostic evaluation to the adjuvant/neoadjuvant therapy and rehabilitation phase. The integration of checklists, guidelines and important medical or other documents is easily accomplished. A direct integration into the hospital computer system is currently not possible for technical reasons.
Conclusion BPMN and t.BPM are sufficiently suitable for the planned modelling and imaging of CP. The application in medicine is new, and transfer from the industrial process management is in principle possible. BPMN-CP may be used for teaching and training, patient information and quality management. The graphical image is clearly structured and appealing. Even though the efficiency in the creation of BPMN-CP increases markedly after the training phase, high amounts of manpower and time are required. The most sensible and consequent application of a BPMN-CP would be the direct integration into the hospital computer system. The integration of a modelling language, such as BPMN, into the hospital computer systems could be a very sensible approach for the development of new hospital information systems in the future.

Keywords Clinical pathway · Business Process Modeling Notation · Tangible Business Process Modeling · Workflow management · Colon carcinoma · Rectum carcinoma

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Introduction

The total impact of clinical pathways is still under evaluation, but it is assumed that clinical pathways will gain more acceptance in the future. Many surgical departments are nowadays working with clinical pathways (CP). The design of CP may differ substantially in individual cases. The exact definition of a clinical pathway as well as its role within the clinical routine is under discussion. CP are, among others, being perceived as tools for quality assurance, process optimization, benchmarking and cost analysis. Critics of CP argue that their introduction is mainly based on economic aspects. With respect to surgery, Ronellenfitsch et al. have shown that clinical pathways can improve objective and subjective quality of care [1]. In an up-to-date Cochrane review, it was shown that clinical pathways are associated with reduced in-hospital complications and improved documentation without negatively impacting on length of stay and hospital costs [2]. The same group has provided the most current and comprehensive definition of a clinical pathway from their detailed literature analysis. According to this definition a clinical pathway has to meet the following criteria: 1) the intervention was a structured multidisciplinary plan of care, 2) the intervention was used to translate guidelines or evidence into local structures, 3) the intervention detailed the steps in a course of treatment or care in a plan, pathway, algorithm, guideline, protocol or other inventory of actions, 4) the intervention had timeframes or criteria-based progression and 5) the intervention aimed to standardise care for a specific clinical problem, procedure or episode of healthcare in a specific population [3].

Based on the positive experience reported in the literature, we decided at our department to develop clinical pathways within a pilot project. We intended to choose a relatively common disease with medium complexity. Thus, we chose two clinical pathways for the treatment of colon and rectum carcinoma. As preliminary theoretical experience with Business Process Modeling Notation (BPMN) was available and we expected a high potential for the description of medical processes from this computer programme, this tool was supposed to be used for this purpose. These days, BPMN is considered to be one of the standards for (business) process modelling. Processes may be described in a text or table form in the easiest way. This does not suffice for complex processes with proper branching, events, detailed administrative units, data flow etc. An appropriate notation is required in these cases. A notation for graphical process modelling defines, among other features, by which symbols the different elements of the process are to be depicted, what they mean exactly and how they may be combined [4]. Such a notation is, thus, the common language for the process description (for further information refer to e.g. www.bpmn.org, "BPMN 2.0 poster" and others). BPMN was developed from 2001 to 2005 and standardised in 2007. The most recent version was published in 2011 (BPMN 2.0). BPMN is thought to be established, cost efficient, rational, standardised, intuitive and flexible. For this reason its implementation for the development of CP would seem to be practical because it can deal with case individuality via different configuration options. A model for all comparable specific treatment processes is being imaged under consideration of alternatives and the procedures that need to be performed. With BPMN, computer based pathway models can be illustrated graphically. They are comprised of few semantically precisely defined symbols for tasks, sub-processes, alternatives, events and their different types. Several levels with e.g. concurrent processes may be imaged (for example, rooms, such as operating room, recovery room and intensive care unit; and different departments, such as anaesthetics, surgery and internal medicine; or organizational units, such as nursing, medical and social services). Complex process steps may be sub-divided into sensible subunits (so-called sub-processes) and may be imaged on the same computer surface. Alterations within the pathway are easily transferable into the graphic image; independently developed documents are being linked with the pathway model by simple clicking, and computations may be performed within the model ("simulation").

In order to familiarize ourselves with the characteristics of the computer programme BPMN intuitively and in a rather playful way, we used Tangible Business Process Modeling (t.BPMN). t.BPMN is similar to a "modular construction system" made of plastic which may be arranged on a large spread-out paper sheet according to the system of BPMN. The process model (or its individual segments, respectively) may thus be critically discussed and altered as appropriate. Once the precise and sufficient imaging of the process is accomplished, the "sketch" is being photographed and finally transferred to the computer [5]. So far, there are only scarce reports about the notation for process modelling in the medical literature, for example the implementation of a free workflow engine technology (XPDL [6]). Specific reports on the application of BPMN in medicine are currently only available from one single group from pathology. This group gives a positive evaluation [7, 8].

This pilot project was expected to answer the following questions:

> Is the transfer of BPMN from the industrial process management for medical applications in principle possible?
> Is BPMN expressively and intuitively applicable for the development of clinical pathways?
> Is the application of BPMN supported by the use of t. BPM?
> What kind of expenditure is necessary for the development of a medium complex pathway model?

Methods

The development was achieved by five persons (one external consultant/moderator as IT project director, one attending surgeon as clinical project director supported by one resident and two doctoral students). For the induction procedure, there was a 1-day introduction to the language BPMN. This was followed by a 3-day period with t.BPM. Further fine-tuning was performed in close co-operation (clinicians and IT professional) mainly on the computer and, for better depiction with flipchart, paper sketches and t.BPM as appropriate. Analogous to the use of BPMN in industry, the general map for the pathway development is in principal always identical: in a first step the requirement is being defined. Subsequently, scenarios, i.e. specific cases, which may differ substantially with respect to complexity, are being described. Then, the structure and the individual design are being developed. This is followed by a test and possibly simulation and optimization. After proper checks the organizational implementation follows as a last step. According to this approach, the treatment process within our own department was depicted as realistic as possible with t.BPM (Fig. 1) as a first step. This included also the complete pre-operative diagnostics, the follow-up treatment including adjuvant and neo-adjuvant treatment, respectively, as well as rehabilitation. The CP were sub-divided according to chronological, administrative or other particular characteristics for logical content. "Raw models" of both pathways have been sketched out since the first day. These sketches that were already in the "proper language" and notation were photo-documented and subsequently transferred to the computer. Resources (time, costs, human resources, equipment or space) may be allocated to specific pathway segments. The software for the modelling of the pathways is Signavio Open Source Process Editor, which is being used as Internet based SaaS variety (SaaS-Software as a Service). In an ideal case, as it was possible with our pilot project, all participating disciplines work closely together under the direction of a clinician and an IT specialist.

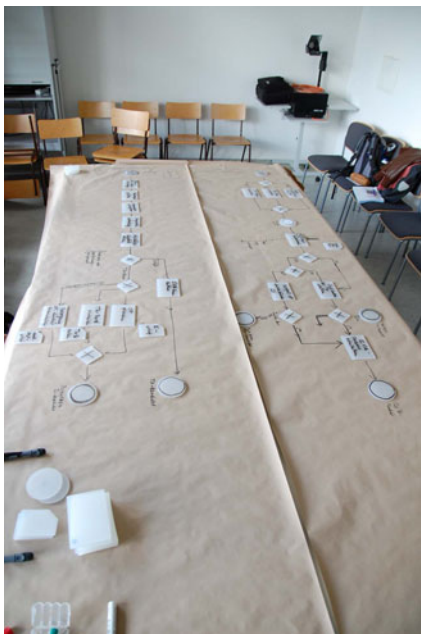

Fig. 1 How t.BPM works

The current S3-guideline for colorectal carcinoma [9] has been used to guide the entire model development. First, we checked in how far our own clinical routine is in agreement with the current S3-guideline. Furthermore, it served as a guide and "checklist" for suggestions and the inclusion of aspects into the CP that had not been considered in the first place (e.g. the issue of "polyp management"). Furthermore, checklists and protocols have been developed by using the guideline. These may be linked as "documents" with the CP (e.g. "risk groups", "Amsterdam and Bethesda criteria", "MERCURY classification").

In the project, numerous interviews have been conducted (e. g. staff from operating room, ward and stoma nurses, anesthesia, ICU, psycho-oncology, social services etc.). Depending on the knowledge of the "core group", we either developed an outline of the respective process step (this was subsequently discussed with the staff and adjusted as appropriate), or the model of the process step was entirely developed with the staff. The interview was conducted in a mainly uniform fashion: what is the content of the process step? Who is responsible? What pre-requisites and resources are required? Are there hiccups or peculiarities? Depending on the requirements, we conducted longer and/or multiple interviews. In most cases the pure interview time was in the range of 30–60 min. All modelled processes were subject to continuing reviews in order to reach a consensus within the team with respect to terminology, outcomes and a realistic picture of the situation (Figs. 2, 3, 4 and 5 show representative examples of specific pathway segments).

Results

Both CP were completed from the diagnostic evaluation to the adjuvant/neoadjuvant therapy and rehabilitation phase. Both CP meet the criteria according to the definition of Kinsman [3]. The development was achieved by five persons with a total expenditure of 55 man-days over 15 working days. During this time, the necessary interviews with medical, nursing and administrative colleagues were conducted as well. The use of BPMN and learning the "language" and symbols were achieved quickly and intuitively. Programming and transferring the sketched process models required considerably more time. Following a 1-day training period, the application of the basic principles was possible with the support of an experienced BPMN application

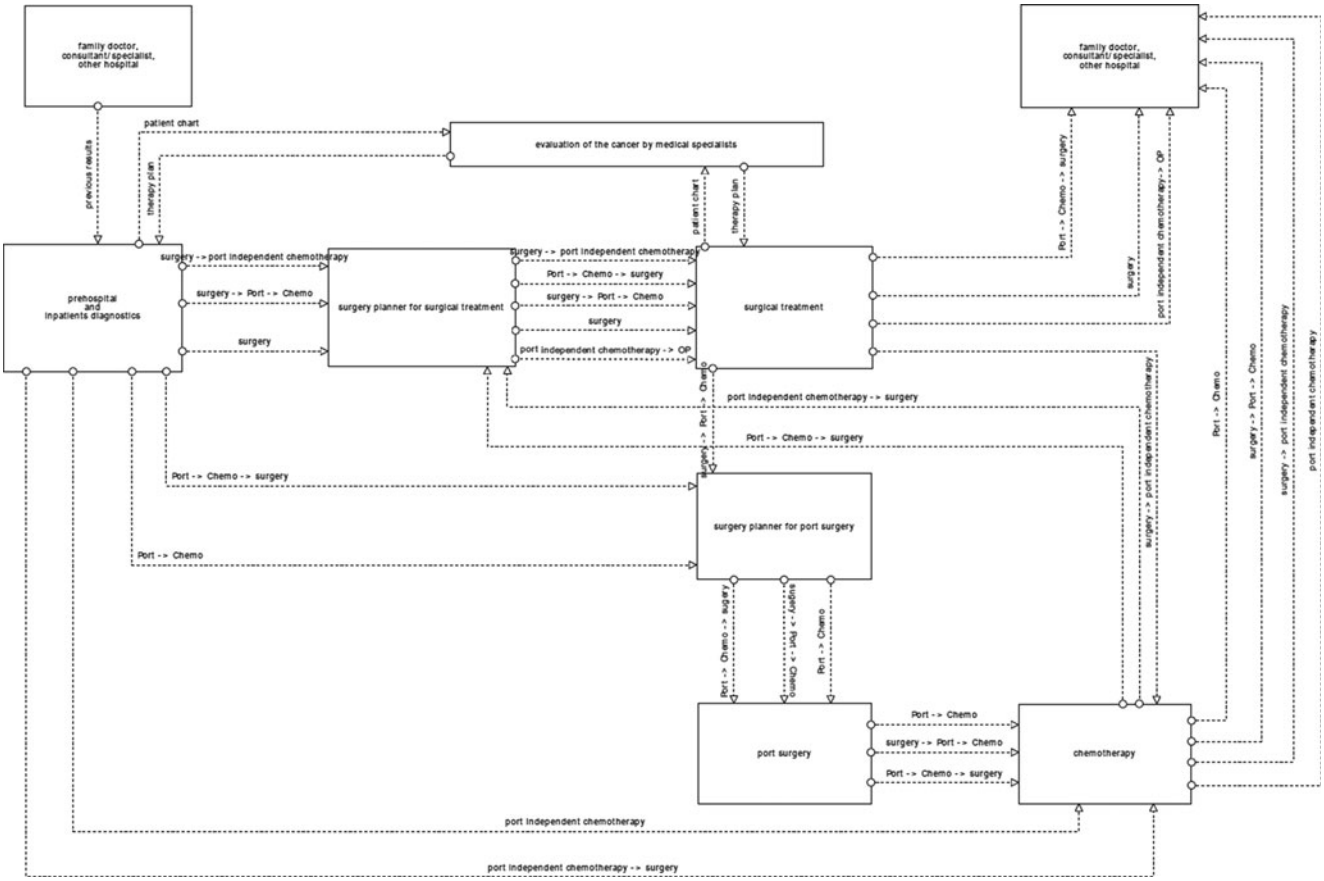

Fig. 2 CP (segment) for colon carcinoma

specialist (RM). With increasing experience the programming of even complex process segments was possible from day 5. The creation of branched process steps which are conducted frequently on several levels has been simplified

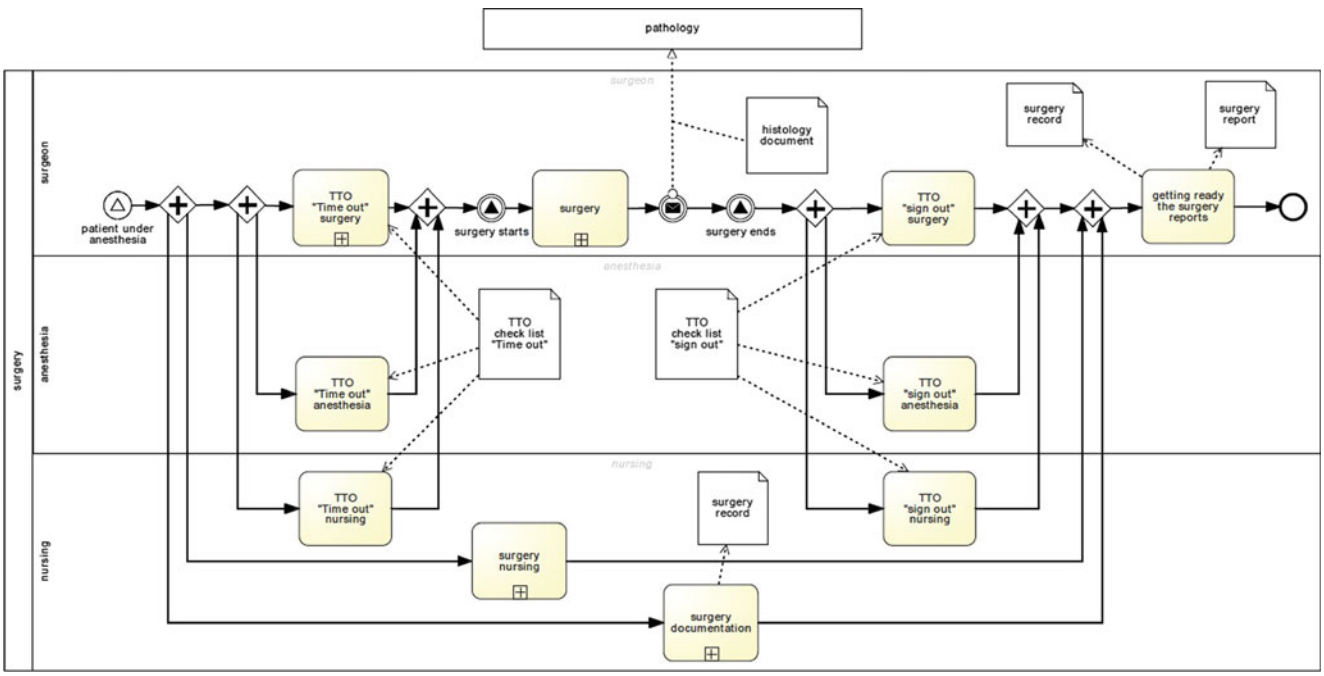

Fig. 3 CP (segment) for the general surgical procedures

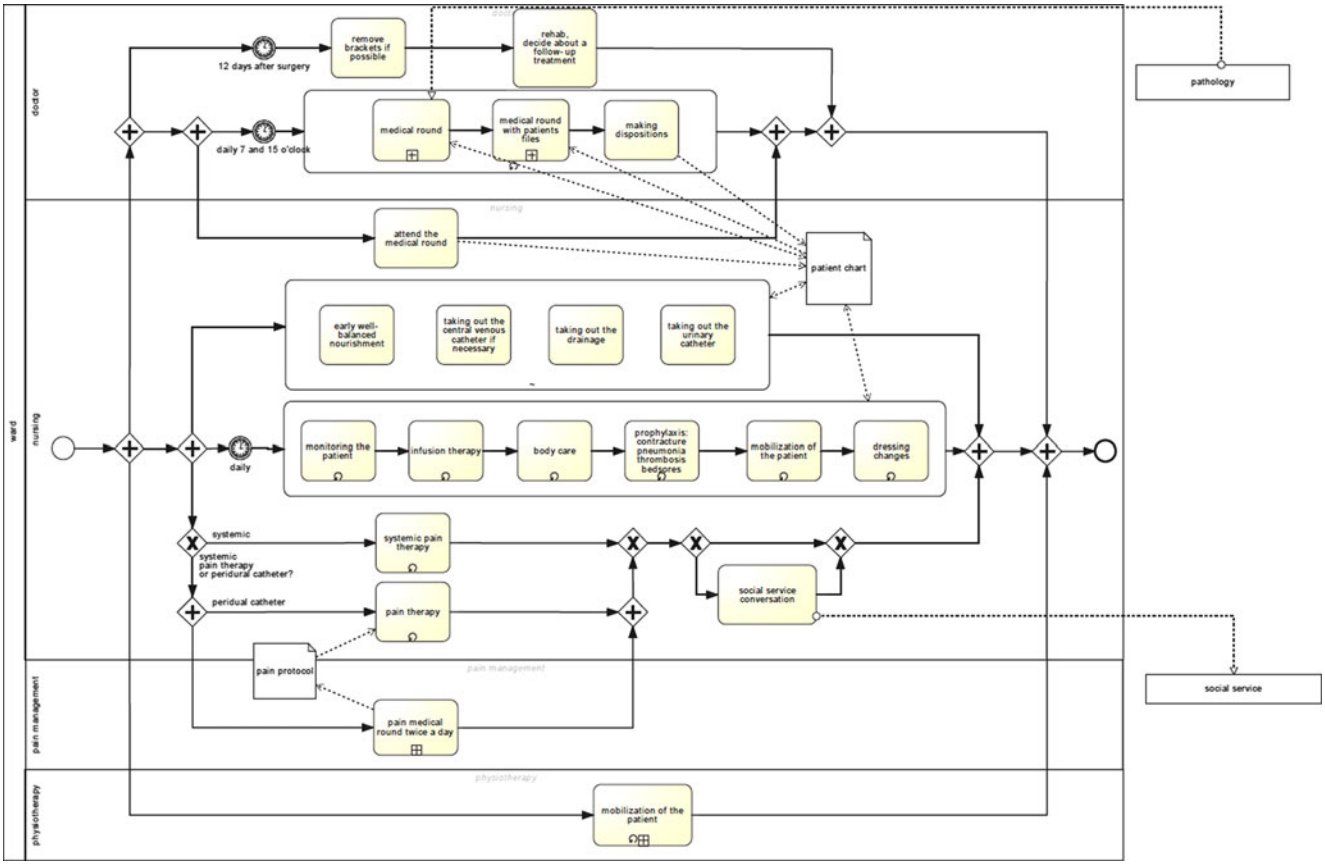

Fig. 4 CP (segment) for the postsurgical care

considerably by the use of t.BPM. The sketches that have been developed were transferred in due course into the computer. Thus, the programming as such was achieved in a goal oriented and effective manner.

Complex pathways have been imaged in a modular fashion with BPMN. The programme proved to be sufficiently flexible even for complex process steps and their interactions. Time scales, work steps, conditions for the initiation of actions etc. have been imaged as a bottom-up approach. In cases of very extensive or complex process steps, these have been subdivided into clearly depicted sub-processes. The scope of common sub-processes is approximately 50% in our project. Documents of any kind (e.g. checklists, reports of examinations, reports of surgical procedures) have been linked with individual process steps in a flexible way. The use of a glossary enabled the co-operative development of the clinical pathway. In this context, glossary means that identical work steps and process steps are being assigned to uniform symbols which may be specific to the individual department/institution. Identical process steps or sub-processes have been used by different staff as there is a common file for individual access.

In summary, after finishing this pilot project the questions that have been posed at the beginning have for the most part been answered positively. The project has laid the foundation work and has enabled the development of basic models and their structural integrity. The programme is sufficiently suitable for the planned modelling and imaging. BPMN also enables an inter-professional analysis and processing of medical–organizational processes. With increasing experience and an extending glossary, synergies have been created with respect to the development of new CP. This is particularly true in cases of co-operation among individual departments or even institutions. One of the essential characteristics of t.BPM is that medical and IT know-how are being brought together in one work process and may be adjusted to the individual requirements. Through the use of t.BPM, the process description which is the most elaborate step of a CP has been performed in an efficient way. The amount of manpower and time for the creation of CP with medium complexity with BPMN is very high, even when the effects of growing experience and synergy are considered.

Discussion

In this present pilot project, we have shown that a standard that is established in the industry for business process modelling can be transferred to the use for clinical pathways. Even though it was not initially designed for use in this

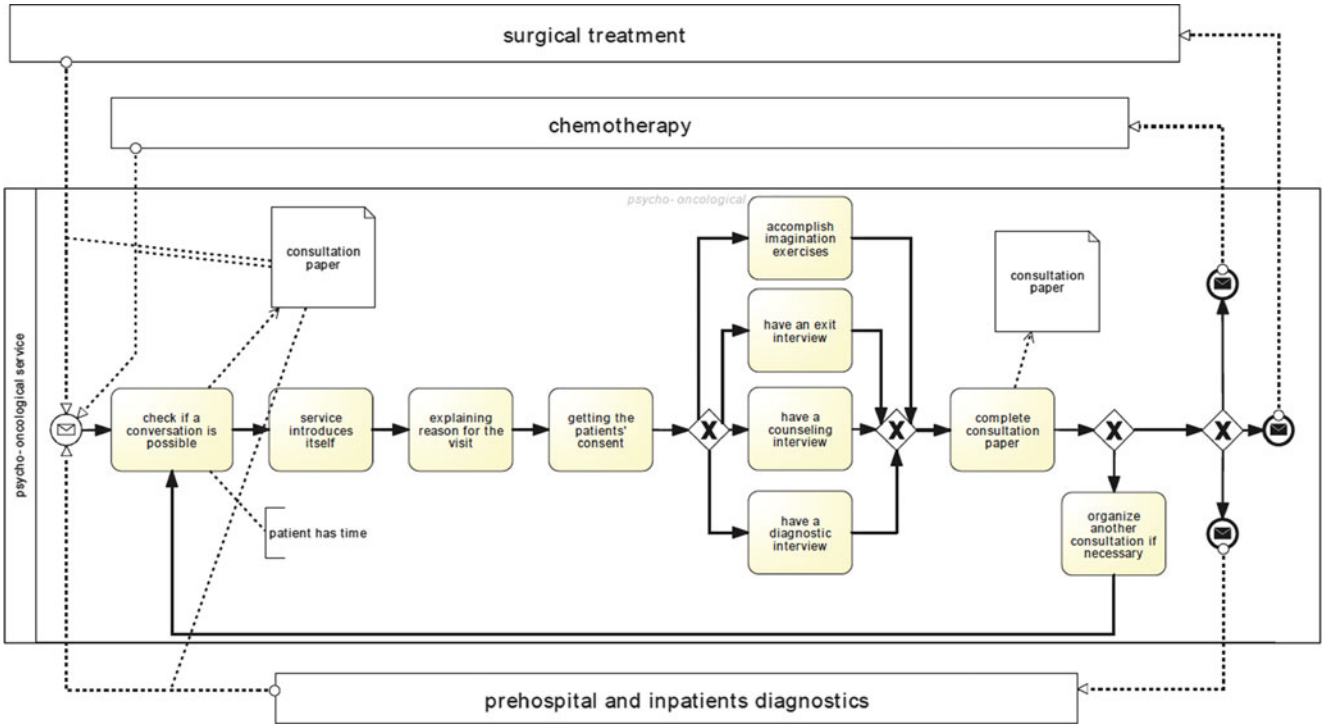

Fig. 5 CP (segment) for the psycho-oncological service

context, a realistic depiction even of branched and complex medical processes is possible. The option of chronological and parallel depiction of process steps is ideal for the description of medical processes. The graphic presentation is appealing and clearly structured. The symbols are easily comprehended after a short learning period, and they are un-ambiguous. Their meaning soon becomes clear even to those who are not familiar with the programme as the symbols can be interpreted similarly to those of a legend of a map. Familiarization with the programming necessitates more time and may require several days, depending on previous experience. The use of t.BPM has proven to be advantageous as it facilitates an exceptionally structured and efficient design of a CP outline.

The essential advantage of this very flexible system is that all those involved work directly in the "BPMN language" on the process and adjust and alter it during the group discussion. Medical and IT know-how are being brought together in one work process and may be adjusted to the individual requirements. The amount of time and manpower required for the creation of CP with BPMN is considerably higher when compared to a depiction in the form of tables or algorithms. It may not be possible to achieve this as part of the clinical routine. As it is true for other CP, a continuous adjustment and updating is necessary. "Modelling languages" that allow for the application of BPMN and graphical depiction of processes as such are available free of charge in some cases. Reports on other standards that are used in the industry, some of them free of charge, have been published with respect to use in medical applications [6]. In this project, we used the software of the Signavio company which has the advantage of statistical analysis, a particularly appealing graphic appearance, comprehensive linking with the internet and as a perspective linking with the hospital information system. There is, however, a charge. For our project, we had professional IT support from an external consultant with long BPMN experience (RM). This is certainly not a pre-requisite, but it was helpful. Initially, a 1-day "BPMN training" had been conducted, and then the use of symbols in t.BPM was started. Thus, the creation of the CP was possible from day 2 in a pragmatic way as learning by doing.

The advantages and, so to speak, the added value with respect to our pilot project are certainly not limited to the graphical creation of the process models for colon and rectal cancer. Rather, they are in the confrontation with the process itself and the associated required structures, resources etc. Thus, they are more or less universal and generally transferable to the creation of any CP (and, thus, primarily independent of the procedural peculiarities).

The use of the S3-guideline has the advantage that it may serve in its structure as a "checklist". Own processes may thus be questioned point by point and adjusted according to the guideline as a whole.

Within BPMN, standard documents (medical letters, reports of surgical procedures, reports of examinations etc.) as well as important documents in the sense of checklists (e.g. Bethesda criteria, MERCURY classification, "algorithm

in cases of suspected anastomotic insufficiency" etc.) may be linked directly with the graphical branch pathway. This makes the thus created CP an interesting tool for staff training and student teaching. The precise details of a treatment can be shown in an easily comprehensible way ("How we do it") on one hand. On the other hand, the establishment of a kind of individual institution-specific encyclopedia is possible: important algorithms, classifications etc. may be looked up any time.

In our case, the interviews which were conducted as personal conversation giving sufficient time for discussion constituted a major part of the project (also in terms of time expenditure). If required, a considerably shorter process may be an option. Just any remaining questions of complete outlines could be discussed, via telephone where appropriate.

With growing experience, work with BPMN becomes quicker and more efficient. Parts of the glossary can be used repetitively. This effect becomes more pronounced with an increasing number of CP developed with this method because the respective identical parts can be adopted completely, or they frequently require only minor modifications.

A direct integration into the hospital computer system is currently not possible for technical reasons. In principle, the most sensible and consequent application of a pathway would be within this context. One of the key questions in this concept is: how can the models be provided with data that are necessary for the simulation or statistical analysis of the pathways? In this context, simulation means that (branching) probabilities may be included into the CP. Thus, it is possible to analyse costs, causes of increased costs, resources etc. Different scenarios may be envisioned according to the motto "what if".

In conclusion, we can state that the application of BPMN in medicine is new, and transfer from the industrial process management is in principle possible. In this pilot project we have demonstrated that BPMN is an expressive and intuitive method for the notation and modelling of clinical pathways. The process of the development of clinical pathways will be substantially simplified and accelerated with t.BPM. Advance training with respect to the language and the use of the glossary is necessary in any case. The initial expenditure is considerable even though BPMN as a method appears to be more time efficient than other modelling methods. A big advantage would be the adoption of pathways that have been developed elsewhere, and/or exchange of pathways. This option is in principle possible with the use of BPMN. In particular, this is interesting for hospitals and departments wishing to use clinical pathways on a broad basis (intersectoral and inter-disciplinary) because the higher the synergistic effects, the broader the basis will be. The obvious advantages of the clinical pathway are clearly with respect to the possibility for education and training. Further valuable options are in the area of quality assurance and quality management. Currently, the missing opportunity to link BPMN models or their execution directly with the hospital computer system is a considerable disadvantage (the problems in this case are due to the so far incomplete technical abilities of today's information systems and in the incomplete support of process descriptions). This is precisely the rationale and the main potential of CP with BPMN. We are currently working on the linking of BPMN with the hospital computer system. It became evident that this is possible in principle but requires major IT efforts in many cases. The integration of a comprehensive modelling language, such as BPMN, could be a decisive advantage in the development of future hospital computer systems.

Conflicts of interest None.

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