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Monitoring care processes in the gynecologic oncology department

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ABSTRACT

The care processes of healthcare providers are typically considered as human-centric, flexible, evolving, complex and multi-disciplinary. Consequently, acquiring an insight in the dynamics of these care processes can be an arduous task.

A novel event log based approach for extracting valuable medical and organizational information on past executions of the care processes is presented in this study. Care processes are analyzed with the help of a preferential set of process mining techniques in order to discover recurring patterns, analyze and characterize process variants and identify adverse medical events.

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1. Introduction

Care processes or clinical pathways are defined as "complex interventions for mutual decision making and for the organization of care processes for a well-defined group of patients. They provide a detailed path that standardizes the coordination of roles and the sequencing of the activities in a multi-disciplinary team for a specific clinical problem or medical procedure" [1,2]. Medical informatics and decision making researchers have embraced the concept of clinical pathways and have used clinical pathways for configuring a wide spectrum of healthcare information systems, e.g. in [3–8]. The main objective of this approach has been the improvement of the provided care by bettering the risk-adjusted patient outcomes, promoting patient safety, increasing patient satisfaction and optimizing the use of resources [9,10]. In reality, the care processes of individual patients deviate from the standardized path in order to accommodate requirements dictated by the patient's specific medical conditions or the local conditions of the healthcare organization [11,12].

In this contribution we present a novel process mining based approach for acquiring insight in the real health care dynamics and the diagnosis-treatment cycles of individual patients. A preferential set of process mining techniques is applied on the data collected by the information systems that support the gynecologic oncology care processes at a major European academic hospital. The approach enables the analysis and monitoring of the provided care and the elicitation of tacit knowledge. Note that the contribution presents an open-minded analysis of the data without any knowledge on the designed pathway, local conditions or specific medical conditions of the patients.

The remainder of the paper is structured as follows: first, the preferential set and the data sources are discussed. Followed by the results of the gynecologic oncology case study, including both the analysis and representation of the general care process information and the identification of adverse events and healthcare risks. The discussion section provides an interpretation of the process mining results and discusses the limitations of this case study. The final section concludes the paper.

2. Methods

2.1. Subjects

The study has been executed on the care processes of 1143 patients of the gynecologic oncology department of a major

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European academic hospital. All diagnosis and treatment activities that were performed for these patients during a period of 3 years, from January 2005 to January 2008 were collected. The patients were all diagnosed with a cancer pertaining either to the cervix, the vulva, the uterus or the ovaries. In total 236 treatment combinations are covered by this set of patients. As will be discussed model comprehensibility will increase when the diagnosis treatment cycles of the different patients are more similar. Therefore, different patient subsets were retrieved for examining specific elements in the gynecologic oncology department, i.e. the radiotherapy and chemotherapy cancer treatment.

Patients eligible for the radiotherapy subset underwent at least one diagnosis (i.e. consultations of different types) or treatment (i.e. teletherapy, hyperthermia therapy and brachytherapy) activity that was performed by the radiotherapy sub department. After filtering out the non-relevant patients we were left with a radiotherapy subset that contains 329 patients. Model development and validation were executed on this subset according to the common conformance checking approaches in process mining [13].

The chemotherapy subset contains the 42 oncology patients that received at least once a paclitaxel based chemotherapy. As this subset will be used for a quality assessment of the care processes for individual patients without the construction of a model, no validation set has been created.

2.2. Data sources

The study presented in this contribution is based on an event log supplied by a major European academic hospital [14], one of the largest academic hospitals in the Netherlands. Healthcare activities for the gynecologic oncology patients have been registered and documented by the hospital financial information systems.

A myriad of information has been recorded for each individual activity including the patient identifier, the activity type, the timestamp, the performer's department indicators and information on both the diagnosis and treatment type. Exactly 150,291 activities or an average of 131.5 activities per patient (spread: 1–1806 activities per patient) were recorded. All activity types (677 in total) are fine-grained and directly related to diagnostic and therapeutic activities of the gynecologic oncology pathways on which the core processes are based. We filtered out all administrative related activities, such as 'order rate' (translation of the activity 'ordertarief'). An example extract of the data set can be found in Table 1.

2.3. Proposal for analyzing care processes with process mining

Process mining techniques enable the translation of huge amounts of activity data, covering the interaction of patients with the hospital, into well-organized descriptions of the actual care processes [11].

In the context of care processes, we distinguish and propose a wide variety of analysis types that can assist in exploring and assessing care process models containing aggregated information on the provided care over a certain period of time, as well as in the evaluation of the care provided to individual patients. An overview of the most important analysis types can be found in Table 2.

Exploratory analysis techniques and tools provide the open-minded analyst with the support needed to acquire novel insights on the actual care processes. These techniques can be easily classified according to the main perspective of the exploratory analysis on the care process. In the context of care processes we distinguish four perspectives [15]: the functional, the process, the organizational and the data perspective.

- Functional perspective analyses deal with the existence (absence) or coexistence of certain process elements, e.g. specific activities.
- Process perspective analyses focus on the exact ordering of the activities. Typical analyses include the construction of an aggregated model for the care processes (i.e. care process discovery) and the discovery of care process variants with the accompanying gap analyses.
- Organizational perspective analyses center on the (human) resource aspect of a care process, including an analysis of the responsibilities, the authorization issues or the social networks.
- Case data perspective analyses revolve around all other types of information that have been recorded in the activity log. Therefore, these techniques are rather suited for clustering the care processes of individual patients and for other correlation analyses.

Advanced care processes analyses techniques focus on assessing the efficiency obtained in the care process, the quality of the provided care and the conformance of the provided care with medical guidelines. Efficiency analyses enable the identification of bottlenecks, e.g. activities that require too much time due to limited availability of specialized resources, in the organization of the healthcare providers. Additionally, they enable the comparison of process variants based on a variety of performance metrics, e.g. number of needed treatment cycles before disease free survival. Quality analyses deal with assessing specific properties of activity sequences for specific patients and the analysis of uncovered adverse events. Conformance analysis compares the provided care with the designed and prescriptive process models, to come to general conclusions transcending the level of the individual patient.

2.4. Overview of applied techniques

In this section we discuss the preferential set of process mining techniques in the context of care processes. Table 3 links the individual techniques to the different analysis types that were

Table 1
Activity log extract.

Patient	Event type	Treat.	Dep.	Diagnosis	Time
155	Follow-up polyclinic consultation	61	SGNA	Gyn. tumors	1-Jan-05
156	Cytological examination vagina	61	LVPT	Gyn. tumors	1-Jan-05
156	Histological examination	61	LVPT	Gyn. tumors	1-Jan-05
275	Teletherapy	13	RATH	Gyn. tumors	1-Jan-05
275	Follow-up polyclinic consultation	13	SGNA	Gyn. tumors	1-Jan-05
336	Potassium flame photometry	603	CHE2	Malign cervix	1-Jan-05
336	Differential count	603	HAEM	Malign cervix	1-Jan-05
336	Determination trombocyte level	603	HAEM	Malign cervix	1-Jan-05
336	Count of leukocytes	603	HAEM	Malign cervix	1-Jan-05
10	Count of leukocytes	113	HAEM	Malign cervix	4-Jan-05
10	Determination trombocyte level	113	HAEM	Malign cervix	4-Jan-05
72	Differential count	3101	HAEM	Malign ovary	16-Jan-05