

Health Care Performance Monitoring Using an Inpatient Reference Process Model and Clinical KPIs

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Abstract. Health care processes are nowadays heavily dependent on Information Technology (IT). On the other side, assessing a higher quality of health care to patients has become increasingly important. Effective health care processes are thereby heavily dependent on a comprehensive IT-support. Therefore, a thorough understanding about both the hospital IT-systems and clinical pathways is required, to identify quality problems. Improving quality of care through process performance measurement in hospitals and the identification of bottlenecks in performed workflows is thereby a promising concept. On this account we propose a novel approach based on an inpatient reference process model aiming a standardized and automated retrieval of quality and performance metrics along the clinical pathways of time-critical diseases in the context of various clinical standards and systems.

Keywords: performance monitoring, clinical key performance indicators, patient process, clinical workflow, clinical process modeling, events.

1 Introduction

With the enormous impact of Information Technology (IT), there is a major demand for standardization in health care nowadays. On the other side, assessing a higher quality of health care to patients has become increasingly important. Effective health care processes are thereby heavily dependent on a comprehensive IT-support. Therefore, a thorough understanding about both the hospital IT-systems and clinical pathways is required, to identify quality problems.

In recent years, hospital performance assessment projects and health care quality reporting have become therefore common worldwide [1], resulting in numerous initiatives aiming the development of clinical quality indicators to measure health care quality including hospital care performance measurement [2]. Improving quality of care through process performance measurement in hospitals and the identification of bottlenecks in performed workflows is thereby a promising concept. Process performance measures can assist hospitals in assessing their workflows and identifying areas for improvements in the field of diagnostics and treatment.

Several health care organizations recognized the importance of using performance metrics to monitor the clinical workflows. However, there is a lack of approaches aiming also the “real-time” end-to-end patient process monitoring, which can provide the possibility, to assist the clinicians in improving the quality of care already during the diagnostics and treatment and not only afterwards. Event-based approaches using workflow-events are a promising opportunity to measure the process performance and to monitor the clinical pathways, to improve the quality of care and benchmark the healthcare organization. On this account we propose a novel approach based on an inpatient reference process model aiming the standardized and automated retrieval of quality and performance metrics like Key Performance Indicators (KPIs) along the clinical pathways of time-critical diseases in the context of various clinical standards and systems. Beside the definition of the new model we develop the required clinical quality metrics systematically and analyze the hospital IT-systems, devices and communication standards regarding the process-based extraction of timestamps. In this paper we describe the conditions behind the approach and the results achieved.

2 Health Care Process Performance Monitoring

Processes are significant components within a health care organization. Process orientation is among others the most important method to support patient-oriented high quality of care. The economical benefit of recognized, well-defined, optimized, IT-supported and hence resulting mature processes is approvable too. Following the international Detecon study [3], a higher maturity of an organization’s processes results directly in an improved Return on Equity (ROE) as well as in an improved Return on Assets and Return on Investment. The resulting positive financial and quality-based effects are exactly measurable [4]. Consequently, to be successful and to provide an efficient and effective diagnostics and treatment, health care organizations have to apply optimization approaches aiming a higher process maturity and improved process performance [4][5].

Health care performance correlates often directly with process performance [5]. Therefore, processes should be applied as an important basis for health care quality improvement. Process models can help to analyze the process quality using structured process descriptions to allow process assessments. Secondly, they provide the basis for improvement steps to achieve a better process performance and in the following a higher quality of the processes within the health care organization. In general, process performance monitoring initiates and supports process improvement within an organization [5].

Thereby, hospitals need reliable and valid indicators for benchmarking and process improvement [6][7]. Following [6], health care process monitoring is impossible without using clinical indicators. Various types of such indicators can be either generically defined to support the measurement of several diseases or specifically defined to provide disease-specific measures [6]. Thereby, process-related indicators enable the performance measurement of the activities and tasks in patient’s “episodes of care” [8]. Based on the performance measurement theories and methodologies derived from industry, they are commonly called Key Performance Indicators (KPIs).

In particular, the development of reliable and valid clinical indicators requires a rigorous scientific design, definition and implementation [9]. Numerous organizations, such as the Institute of Medicine (IOM) [10], accrediting organizations (JCAHO, NCQA), government healthcare research and quality agencies (AHRQ, CMS) and various research groups devise and publish clinical indicator sets for measuring purposes in various domains of quality of care [11]. However, not all of these indicators are considered by physicians or hospitals to be valuable or relevant in their practice. Furthermore, health care systems are complex and therefore indicators may not reflect accurately all aspects of quality [12]. Another problem is that their development is frequently driven by feasible availability of data or ease of measurement, rather than by an objective definition of important clinical indicators [5]. Consequently it is essential to define indicators involving all stakeholders like physicians and IT-experts and additionally to consult approved guidelines, to ensure the indicator relevance, reliability, reproducibility and validity [11] and provide the possibility to develop both generic and disease-specific indicators.

We focus on clinical quality of care indicators and relate to the processes, which are performed in the care of time-critical diseases. The usage of time-based indicators for quality assessment in time-critical workflows represents a possibility for measurement, documenting and improving the quality of care [13][15]. Aiming the collection of time-based indicators in hospitals required IT-timestamps have to be retrieved. IT-systems act in our approach as enabler for performance monitoring, clinical quality improvement as well as risk and cost reduction [14][16]. The involved IT-systems are the Hospital Information System (HIS) and in the radiology department: the Radiology Information System (RIS) and imaging devices (Modalities). Outside the radiology department the Laboratory Information System (LIS) is used. Because several systems and communication standards (DICOM and HL7) (see Fig.1) are involved in the clinical workflow, we developed a new inpatient process model to enable performance monitoring across several clinical systems [16].

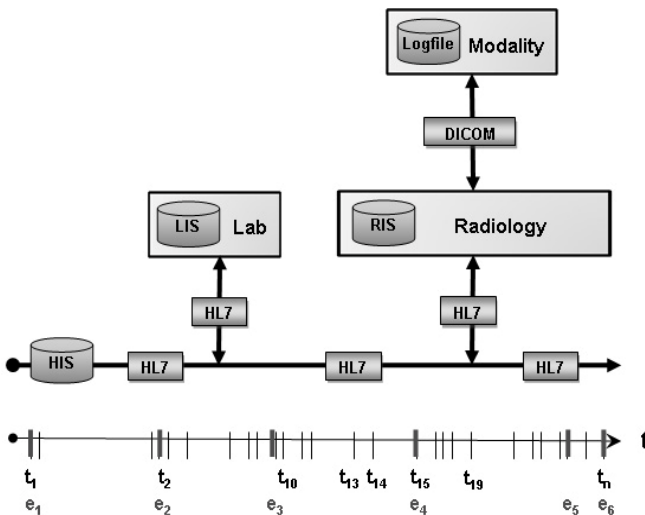


Fig. 1. IT-systems and clinical standards involved in the diagnostic workflow in hospitals

Fig.1 shows the involved IT-systems and the timeline during the diagnostics of an inpatient (i.e. a patient who stays at hospital for diagnostics and treatment). Additionally, timestamps (t) and events (e) are exemplary marked in the figure. Event (e1) means the patient's admission at hospital. The two following events mark the beginning and the end of the laboratory procedure, i.e. the KPI "order to lab test". The fourth and fifth events allow the imaging procedure monitoring at a modality (i.e. imaging device). Here the KPI "order to imaging" can be determined. Thereby, the timestamps, these events are based on, are extracted from the logfiles stored at the modalities. Using modality logfiles for monitoring purposes is a novel approach we introduce to enable process monitoring at the lowest process level. Finally, the last event indicates the finishing of the diagnostic process flow. The difference between the first and last event timestamps provides the KPI "door to diagnosis", which is very important in time critical diseases like heart attack and stroke [17].

3 Results and Validation

We developed a new generic inpatient reference process model to provide the possibility of standardized and comprehensive performance process monitoring in hospitals in the field of time-critical diseases. In order to monitor the process cycle times, health care organizations are up to date faced with the problem of extracting IT-timestamps from several not well-connected IT-systems, which are not related to a specific inpatient process. Consequently, it is not possible to monitor the whole end-to-end inpatient process-flow starting with the patient's admission at hospital until the patient's discharge. Secondly, valid and reliable performance monitoring requires standardized, meaningful and well-defined timestamps and events, which have to be monitored in order to measure the process cycle times. We provide these possibilities and fulfill both requirements bridging the gap between the IT and the clinical context proposing our model and KPIs [16]. As the definition of such events and the indicators based on them is very time-consuming and difficult [13], a predefined generic approach - as we present it - is desirable by the stakeholders. It can be used already in an early phase during the assessment in hospital to analyze the pathways and to define the measure points based on the IT-system architecture [14].

The first model development phase comprised the construction of our newly clinical reference process model using events, functions, connectors, control flows and process path elements. We selected the relevant process tasks based on interviews we performed with sophisticated clinicians. This group was built up of physicians like cardiologists, neurologists and radiologists who have huge and long-time experience in hospitals in heart attack and stroke treatment. Individually observations of the workflows during diagnostics and treatment of heart attack and stroke patients in several hospitals built up the second information source. After finishing the modeling tasks the physicians were consulted again in order to approve the model, the acceptance of the chosen modeling technique as well as the clinical correctness. In further steps we enhanced the model analyzing clinical pathways, as they are used in best practice hospitals. "Best practice" means in this context, that the considered hospitals are best in treating heart attack resp. stroke regarding quality of care.

In the following, we conducted interviews with involved physicians again, to derive relevant, valid, reliable and feasible clinical indicators for process monitoring. Additionally we consulted clinical guidelines for stroke and heart attack treatment. We derived sets of time-based indicators following [18],[19], which we approved again with experienced clinicians. Afterwards we generalized the indicators to use them in our generic reference process model. Finally we investigated the IT-infrastructures, which are nowadays commonly installed in hospitals.

To provide process-based and integrated performance measurement support we selected the event-based process chain (EPC)-method for modeling. EPCs have become widely-used for business process modeling in Europe, in particular in countries where SAP acts as a leading Enterprise Resource Planning (ERP) system [20]. EPCs are inspired from petri nets, incorporate role concepts and data models like ER-models or UML class diagrams [20]. According to [21], the EPC belongs to the most advanced business process modeling languages beside the UML and is one of the most used languages in the measurement researching community [22].

We evaluated and verified our approach with several clinicians and medical specialists applying it in the hospital environment. Therefore we simulated the clinical pathways of several hospitals using our EPC-model in the ARIS-Toolset. ARIS provides the possibility to test and to simulate the modelled processes already at design time, i.e. before an implementation in the clinical IT-environment is started or performed. An integrated “Process Performance Manager“ (ARIS PPM) can be used for process cycle times analysis purposes. ARIS PPM extracts information from logfiles and shows them graphically including process bottlenecks. The second evaluation step involved the mapping of the IT-systems, which were used in the hospitals in question to the modelled events. Thereby, the events, which can be automatically extracted, were identified. Finally the derived clinical indicators were evaluated again in discussion with clinicians as well as through a comprehensive literature study.

The objective of this practical validation was first to demonstrate the applicability of the approach in the hospital environment. This included the approval of the appropriateness of the modelling approach. First, the used EPC-methodology was approved as understandable for clinicians and as practicable for process monitoring in hospitals. As we modelled and use separate EPC-modules in our approach, which are loosely connected using process interfaces, we assure the flexibility that is required in such a highly flexible clinical environment. This means that several diagnostic and treatment procedures as well as performance measures can be repeated and performed in parallel if it is necessary. Finally, our modelled generic indicators were approved as *relevant, valid, reliable* and *feasible*. They are *relevant* because they relate to clinically important, evidence-based aspects of care over which clinicians have significant control. Furthermore they are *valid* as they correlate strongly with the measurement goals. Very important was the approval of the indicator *reliability* as the indicators are mapped to selected model events and therefore valid for comparison and standardized recording. Finally, the indicators are *feasible* as they are sustainable over time. In future work we will formalize our approach stronger and consider a graph valuated mechanism therefore. As we focus on time-critical diseases, a

statistical evaluation would require a comprehensive study involving several hospitals. In near future, statistical results will be provided therefore using simulation.

4 Related Work

So far, there is no process model published that describes the integration of clinical performance metrics for acute diseases taking in particular into account the possibilities for their automatic extraction using clinical information systems during a patient's stay in hospital and additionally considering the characteristics of the clinical environment, such as flexible workflows and modular process structure. Nevertheless, focusing on classical workflow analysis, event-based process monitoring and mining approaches with the objective to optimize the workflows are presented in [23], [24], [25] and [26]. However, they were not designed for health care purposes and focus on more standardized processes as they are usually performed in clinical domain. An identification approach aiming the clinical context identification and categorization is proposed in [27].

A KPI-based framework for process-based benchmarking of hospital information systems is presented in [28]. In contrast to our approach, documentation processes and outcome criteria related to the process flow and underlying structures in the area of the Hospital Information System (HIS) aiming benchmarking possibilities are there focused on. An approach using the derivation of hospital-specific clinical guidelines is described in [29]. Thereby, lifecycle support for medical guidelines and pathways is the objective.

Further clinical (reference) process models are presented in [30], [31], [32], [33], [34]. In [35] the authors present a modeling approach, which introduces principles of process modeling in healthcare using EPCs and employ these principles to existing medical information systems by implementing them using a Workflow Management System (WFMS). However, the possibility for event-based clinical performance measurement in time-critical diseases, as we introduce it in our approach, is not provided. Additionally, the model-based generic and disease-specific performance monitoring is also not supported.

5 Conclusion and Outlook

Especially in the field of time-critical diseases, performance monitoring and measurement is important regarding process optimization and quality improvement in hospitals. Our approach comprehends performance monitoring using standardized time-based performance indicators based on clinical IT-systems and standards as well as the developed inpatient clinical process model. In future work we will investigate the usage of our approach in clinical workflow engines to provide the possibility to manage and improve the IT-based workflow execution and to enable process mining.

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