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December 2007

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Recommended Citation

Becker, Joerg; Fischer, Robin; and Janiesch, Christian, "Optimizing U.S. Health Care Processes - A Case Study in Business Process Management" (2007). *AMCIS 2007 Proceedings*. 504.

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Optimizing U.S. Healthcare Processes: A Case Study in Business Process Management

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Abstract

Inconsistent and incomplete information due to the diversity of isolated information architectures in modern healthcare enterprises is one of the major problems information technology has to face in healthcare. The approach of this work is to apply existing Business Process Management principles to medical information systems providing healthcare enterprises a reliable and timely access to relevant patient information. In doing so, this work outlines a workflow implementation of a clinical infection control process done in collaboration with a major healthcare provider and a regional healthcare facility in the U.S. The workflow utilizes the Health Level Seven (HL7) communication standard to integrate disparate systems and to automate clinical decision making according to clinical knowledge. The final data analysis clearly emphasizes the capability of Business Process Management to improve the integration of information, increase the quality of patient care, reduce health worker's stress, and reduce costs of treatment.

Keywords

Business Process Management, Workflow Management, Healthcare, Infection Control, Health Level Seven

1 Introduction

Hammer and Champy (1993) see the practice of automating existing processes as “paving cow path” compared to major Business Process Reengineering (BPR). However, this rather radical approach is not suitable for all business fields. It requires the freedom to modify organizational structures and free core business processes from non-value adding activities. In business sectors like healthcare, there are a variety of legal restrictions and treatment guidelines practitioners have to comply with (The Medical Letter Inc. 2004; The Medical Letter Inc. 2006). Hence, freedom to reorganize the organization and to omit non-value adding activities is heavily compromised.

The approach of this work is to introduce the less radical principles of Business Process Management (BPM) (Becker et al. 2007; van der Aalst et al. 2003) to healthcare and employ these principles to existing medical information systems (IS) (Borst et al. 1999; Gardner et al. 1999; Teich et al. 1999). By this means, we outline potential for process optimization, i.e. reduce cost, free staff from routine work, and improve patient safety without reengineering the company, despite a restrictive environment and legal pre-requisites. A case is performed to show how BPM and information technology contribute to lower the frequency of human errors in healthcare (Institute of Medicine 2001; Kohn et al. 2000). The case study originates from a customer project in the U.S. The goal of the project was to improve efficiency of the existing controlling process for hospital acquired infections (HAI).

The structure of the paper is as follows: In the following section, we perform a literature review of available process definitions as basis for a brief discussion of BPR and BPM. Section 2 introduces healthcare and clinical processes as a foundation for the characterization of infection control. Section 3 comprises the case study which is conceptually explored. The paper closes with conclusions to an outlook.

2 Healthcare and Clinical Processes

Processes

Processes are generally seen as any activity performed within a company or an organization (Object Management Group 2006). Thereby, activities are considered to be the smallest entity used to build a process. Those entities may be seen as complex chunks, which for some reason do not need to be analyzed further, or atomic activities, which cannot be divided any further. Furthermore, an activity can either refer to work that is done manually or to work that can be done automatically (Harmon 2003). Other definitions (Davenport 1993; Johansson et al. 1993) emphasize on the timely and local order of activities and also regard different kinds of inputs and value-added outputs. In another approach, business goals to which processes are tied to, are stated to be significant for the definition of a process (Harmon 2003). Each of those definitions fails to integrate all relevant perspectives into one consistent definition. In the context of this work, a process is therefore defined as “a completely closed, timely and logical sequence of activities which are required to work on a process-oriented business object” (Becker et al. 2007), as this definition integrates all relevant perspectives.

Consequently, we consider a business process as a special process that is directed by business objectives of a company and by the business environment (Becker et al. 2007). Business processes can be further classified into value creating core business processes and not value adding supplementary processes. Whereas core business processes are considered to contain corporate expertise and create products or services that are delivered to customers (Harmon 2003; Porter 1985), supplementary business processes facilitate the ongoing operation of the core processes. This distinction is not intended to be always selective as one business process might be a core business process for one product and a supplementary business process for another (Becker et al. 2007).

The practice of BPR, which emerged in the early 1990s, is seen as fundamental rethinking and radical redesign of business processes. In doing so dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service, and speed can be achieved (Hammer and Champy 1993). This kind of greenfield project, however, does not consider any existing operational sequences or organizational structures during the building of new processes at all and lacks granularity with respects to process hierarchies. Furthermore, BPR targets the overall process perspective in one single shot rather than iteratively and continuously optimizing processes' performances. BPM on the other hand serves the planning, controlling, and monitoring of intra- and inter-organizational processes with regards to existent operational sequences and structures, in a consistent, continuous iterative way of process improvement (Becker et al. 2007).

Healthcare Sector

Healthcare providers are under constant pressure to reduce costs while the quality of care is to be improved (Institute of Medicine 2001). Expenses for patient treatment and pharmaceuticals are relentlessly rising whereas reimbursements, refunded by insurance providers, are coupled to diagnosis-related groups and fixed (DiMasi et al. 2003). Diagnoses related groups allow classifying of patients in segments of comparable diseases. Every group has an assigned basis value for reimbursement. The actual reimbursement is calculated by taking the actual severity of the illness into account (Mast et al. 2004). Despite these efforts, the healthcare system in the U.S. is the most expensive healthcare system in the world. Health spending as share of the Gross Domestic Product (GDP) in 2004 has been 16,3 %, which is almost double the average (8,9 %) of all countries listed by the Organisation for Economic Cooperation and Development (Organisation for Economic Cooperation and Development 2006).

Clinical Processes

Clinical processes can be classified as generic process patterns or medical treatment processes (Lenz and Reichert 2005; Panzarasa and Stefanelli 2006). Both types of processes may be designed and executed cross-department as well as cross-company. Generic process patterns help to coordinate healthcare processes among different people and organizational units. Medical treatment processes are the representation of an actual care process, which are considered the core processes of healthcare facilities. These processes highly depend on medical knowledge and case specific decisions (Panzarasa and Stefanelli 2006). Clinical process decisions are made by interpreting patient specific data according to clinical knowledge. In order to provide clinical decisions support, patient specific data is consolidated and a recallable representation of clinical knowledge is provided in medical IS. The cooperation of clinical knowledge and complex decision support allows the implementation of treatment guidelines in highly flexible processes. Flexibility is required since treatment of patients is likely to differ from patient to patient. In consequence, medical treatment processes have to be quickly adaptable (Lenz and Reichert 2005). Medical treatment processes can be further described as a diagnostic-therapeutic cycle. Main components of

the diagnostic-therapeutic cycle are: observation, reasoning, and action. These stages are iterated until no further action needs to be taken, i.e. the patient no longer requires treatment (Lenz and Reichert 2005).

Information Systems in Healthcare

The historical evolvement of heterogeneous IS in healthcare may be due to a lack of expertise in implementing systems, missing investment abilities, but also the development of technology needs to be taken into account (Magruder et al. 2005; Wisniewski et al. 2003). In order to provide a minimum of data integration, standards like *Health Level Seven (HL7)* define a standard for the exchange of data between clinical applications. HL7 defines which data is interchanged, when certain clinical events occur (Health Level Seven 1998). In addition, *Arden Syntax* was also developed under the umbrella of HL7. Arden is used to define complex clinical conditions in clinical rules so called *Medical Logic Modules (MLM)* (Shwe et al. 1993). Each MLM is written in a procedural programming language and stored in single files to enable intra- and inter-organizational exchange of medical knowledge (Health Level Seven 2005; Pryor and Hripcsak 1993). MLM are organized in so called slots. The invocation slot, for instance, defines which event triggers the execution of the MLM. Whereas the logic slot defines the criteria that are evaluated before an action is executed.

Infection Control

Infection Control (IC) is the process of preventing hospital acquired infections (HAI) by isolating sources of infections and limiting their spread. Nowadays, HAI are by far the most common complications affecting hospitalized patients or intensive care patients (Borst et al. 1999; Centers for Disease Control and Prevention 2004; Teich et al. 1999). Approximately 2 million patients are affected each year and costs add up to estimated \$4.5 to \$5.7 billion per year (Burke 2003). Identification of HAI typically involves testing of specimen in a laboratory. In addition, nurses working at nurse stations need to get specimen, physician need to order the specimen tests, and finally Infection Control Practitioners (ICP) need to ensure that all precautions have been taken, if a specimen was tested positive.

3 A Case Study in Business Process Management in Healthcare

The present case was performed by Siemens Medical Solutions USA, Inc. (Siemens MED) and a major health care facility in the U.S. The facility consists of multiple independent hospitals. More than 7500 employees are employed at four sites, medical staff counts around 1000 physicians throughout the organization. Overall, almost 1000 beds are available for inpatient care. In the following, the organization will be referred to as customer.

The scope of the project was to analyze the current IC process, suggest possible improvements through workflow, and finally enhance the current IT solution to increase process efficiency. The project was started in April 2006, when analyzing the existing processes and taking pre-measurements took place, and ended in September 2006 with the completion of post-measurements. Measurements were designed in a way that enabled comparison of turnaround times before and after the implementation of the automated workflow. Build, test, and integration of the workflow were done in only twelve weeks. Table 1 provides an overview of the project phases and the collection of data.

Phase	Timeline					
	April '06	May '06	June '06	July '06	Aug '06	Sept '06
Analysis (as-is modeling)						
Design (to-be modeling)						
Implementation						
Testing						
Evaluation						
Data collection: pre-metrics						
Data collection: post-metrics						

Table 1. Project plan

Project Environment

The medical IS used in this project is called Soarian®, developed and distributed by Siemens MED (Siemens AG 2007). In the following, we outline the deployed architecture to provide an overview of how a workflow management system (WfMS)

is integrated into the environment. The WfMS used in the Soarian® environment is the third party product TIBCO Staffware Process Suite. The WfMS can utilize services provided by Soarian® to add and remove items to/from role and user specific worklists in Soarian®. Worklists are components of the Soarian® User Interface enabling the WfMS to alert users in case of required user actions. On the other hand users of the Soarian® User Interface are able to trigger events, hence invoke the workflow engine to perform actions on demand. Whereas simple routing conditions can be evaluated by the WfMS itself, complex clinical conditions are evaluated with respects to clinical knowledge and patient specific data. Therefore, a rules engine based on Arden Syntax can be utilized by the WfMS to evaluate complex conditions. For information on clinical data sources cf. Wisniewski (2003).

As-Is Analysis

According to the project plan we presented earlier, the first project phase comprised the analysis of the current IC process. Therefore, we conducted interviews with all involved actors (e.g. clinicians, nurses, laboratory workers, and ICP). The combination of all expert interviews resulted in a comprehensive as-is process model:

The IC process used by the customer consists of two separate process fragments, synchronized over paper reports. The first part of the process starts as soon as a specimen is tested, if the patient to which the specimen is assigned to, is an inpatient at the customer. First, the lab result is checked whether it indicates a positive statement of a HAI. This is done by the laboratory, which has already performed the test of the specimen. An IS is used in the laboratory to support this task. Once a lab result indicating a positive infection statement has been identified, an employee working at the laboratory calls the floor the patient is located on. In doing so, the nurse station is notified about an infectious patient and responsibility for putting the patient in isolation is passed to the nurse station. After the nurse station has initiated necessary tasks to isolate the patient, the first part of the IC process ends, as soon as the laboratory has completed the documentation of the lab result in the lab system. The event-driven process chain (EPC) (Scheer 2000) depicted in Figure 1 illustrates a structured overview of this part of the IC process.

The second part of the IC process is rather a controlling process, as each hospital must report the amount of infection occurrences on a yearly basis (Weber et al. 2007). As for this customer, specific reports for each infectious disease were created on a monthly or even daily basis. These reports are the starting point of the second fragment of the IC process (cf. Figure 2). Once a report of an infectious disease is received by an ICP, the report is checked for infection statements. This task results in a list of patients that need a follow-up ensuring that patients who require isolation are actually put in isolation. During daily tours, the ICP does not only check if infection precautions have been taken for infectious patients but also controls, if the infection statement is transferred to the patient's chart. If a patient is not put in isolation, the ICP immediately initiates isolation.

Through the analysis the following intrinsic problem domains have been externalized:

- *Lack of synchronization:* Since reports of infectious diseases are generated every afternoon, even on weekends, and every Friday afternoon respectively, an ICP does only recognize infections the morning after the report has been generated. However, these reports are triggering the execution of the second part of the IC process. Hence, they are critical in time.
- *No use of information technology:* The analysis of the IC process clearly revealed that no information technology is used after the ICP has received infection reports. In addition, further investigations indicated that ICP did not have any access to Soarian®, yet.
- *Excessive time spent screening infection reports and charts:* The review of reports and patient charts are done manually as infection reports are printed and corresponding patient charts are not at hand instantly. A sample inquiry performed in collaboration with ICP indicated that screening all necessary documents takes almost 30 % of ICP's daily work time.
- *Involvement of ICP in notification tasks:* Even though ICP have responsibility for the handling of infectious diseases, they are not directly participating in the IC process. Further inquiry revealed that the former process was to leave a voicemail for the ICP, assigned to the nurse station the patient was located at, as soon as an infection disease was stated. Once the ICP received the voicemail, the isolation of infectious patients was initiated and controlled by the ICP. However, since ICP do not work nights or at weekends this process was changed to directly call the floor and notify ICP only through reports. In doing so, the customer reported faster turnaround times in putting patients in isolation even though notification of ICP was delayed, i.e. follow-up processes start delayed.

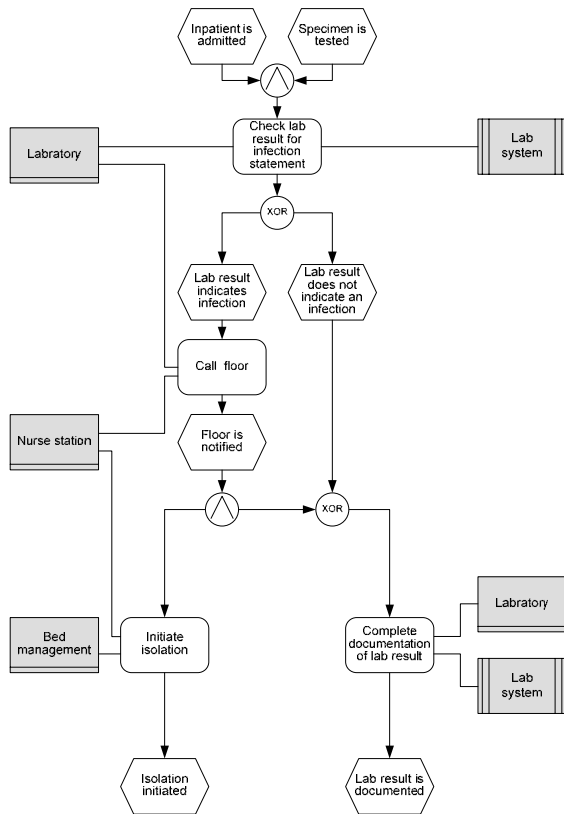


Figure 1. As-is notification process

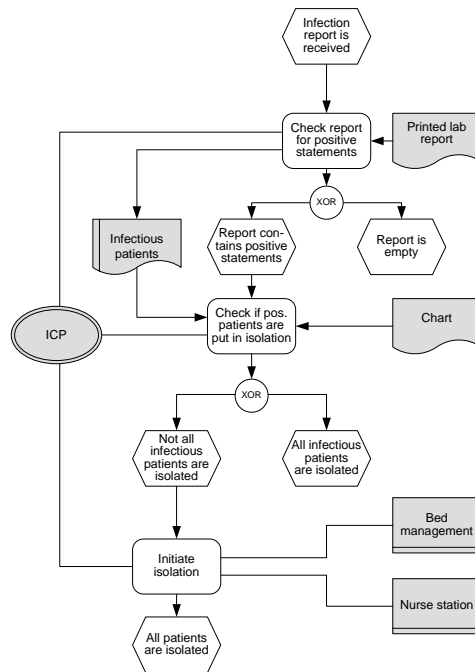


Figure 2. As-is follow-up process

To-Be Analysis

It became obvious that no change in matters of personnel capacities could be made. Neither could the involvement of ICP in notification tasks be increased nor could the controlling responsibilities of ICP transferred to an IS due to legal prerequisites (Weber et al. 2007). The laboratory will still have to notify the nurse station directly, as ICP will, yet, not work during night hours or on weekends. In addition, it was agreed to not work on further improving the turnaround time for putting patients in isolation, but on the elimination of time wasted while generating, delivering, and reading reports as well as screening patient charts. In doing so, it was agreed to optimize IC tasks done by ICP without affecting existing other clinical and business processes.

Therefore, we put focus on synchronizing the infection notification (cf. Figure 1) and the follow-up (cf. Figure 2) fragments of the as-is IC process. We suggested the introduction of a new workflow supported IC process. The workflow should be used to screen new and modified lab results for statements of infectious diseases. Therefore, events defined by HL7 have been used. In doing so, the workflow is subscribed to new and modified lab results events (HL7_R01 and HL7_R02). As the case study was a pilot project, it was agreed to limit the workflow to only cover two infections: Clostridium difficile (CDIFF) and vancomycin resistant enterococcus (VRE). However, the workflow could be easily extended to cover other HAI, once clinical conditions have been identified and MLM are created for an automated evaluation of those conditions.

Figure 3 illustrates the notification process of the to-be IC process. According to the agreement made with the customer, this part of the IC process was not changed at all. However, the linkage between the notification process and the infection follow-up is made explicit in the to-be process models. Therefore, the interface “Follow up” and “Notification” have been added to the notification process and to the follow-up process respectively. In doing so, the follow-up process is started immediately after the notification process and valuable process time is saved by synchronizing both processes parts.

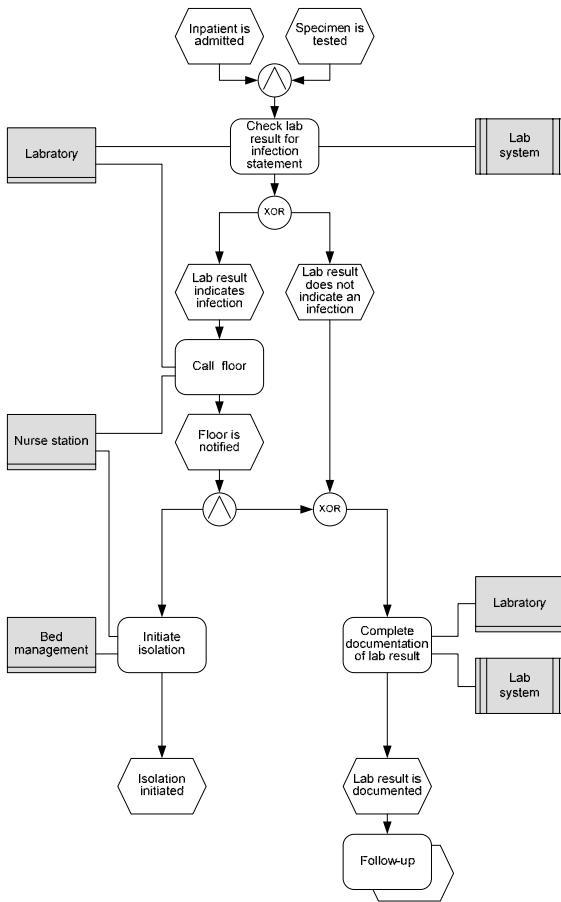


Figure 3. To-be notification process

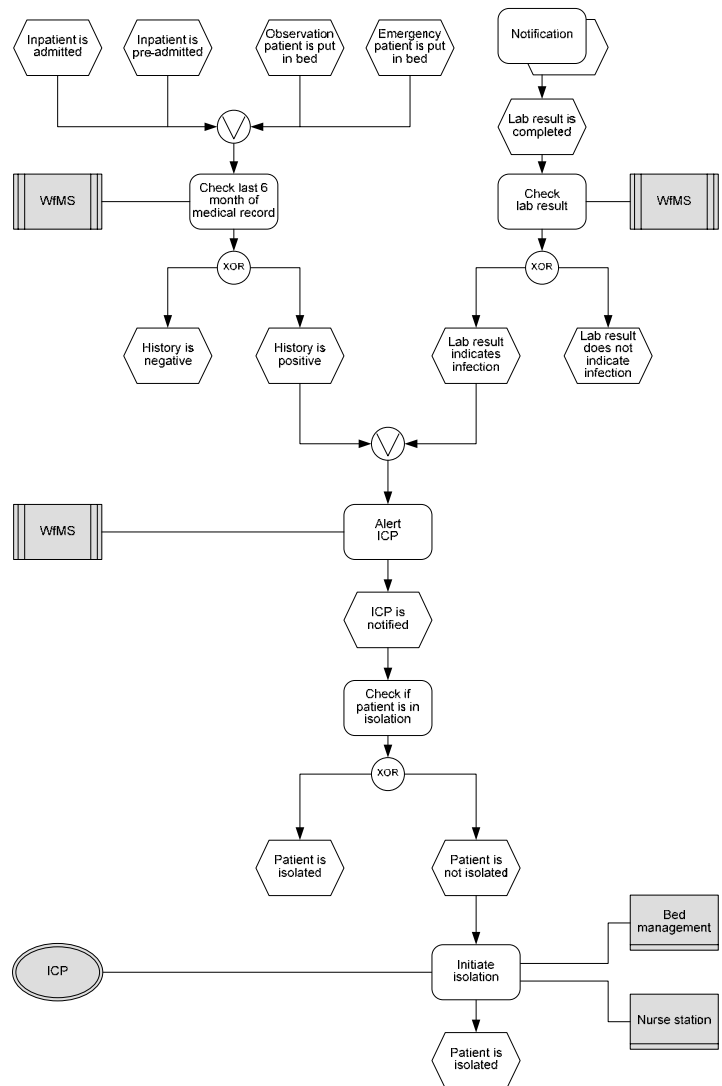


Figure 4. To-be follow-up process

More significant changes have been made to the infection follow-up process that is shown in Figure 4. The process has been streamlined in order to allow efficient automation through the use of a workflow. To achieve the requested level of automation a WfMS has been introduced to the process. In addition, the process takes advantage of the fact that ICP are able to access to Soarian® as further IT support is provided in the remaining manual tasks.

The follow-up process is triggered every time a lab result is documented in the lab system. The lab result is immediately evaluated through workflow. Only if the lab result either indicates a positive CDIFF or VRE statement, the ICP assigned to the nurse station the infectious patient is located at, will be notified. The notification, once again, is performed automatically through workflow. Hence, ICP will instantly see a new task on their worklist in Soarian®. The validation whether a patient has been put in isolation still is done manually, but ICP are now able to access medical records electronically in Soarian®. This enables ICP to work independent of any paper reports or patient charts. Unfortunately, initiating the isolation of patients is executed and monitored manually due to missing integration of participating actors (e.g. bed management).

In consequence of extensively implementing the IC process with the use of IS, new possibilities for further process enhancement have been established. Utilizing new benefits, the to-be infection follow-up process was designed to be executed not only every time a lab result has been documented but also every time a patient is admitted as inpatient, an inpatient is pre-admitted, an outpatient is kept in hospital for observation or a patient requires emergency care (cf. Figure 4).

In either case, the last six month of the patient's medical record are screened for an occurrence of an infection. If an infection statement was found within the past six months, the patient is considered to require isolation and infection precautions are taken. Since many HAI (e.g. VRE), are likely to reappear, if the last infection is more recent than six month, these new characteristics enabled the increase of process quality and patient safety in addition to the increase of efficiency.

Project Controlling

Concurrent to the project realization data was collected for a detailed analysis of the project outcome. We designed pre- and post-metrics to measure the performance of the IC process before and after the implementation of the workflow supported IC process. The key metric we defined in collaboration with the customer is *time to notification*. Time to notification as measurement of time, represents the time spent notifying an ICP of a newly identified infectious patient. In doing so, time measurement was started as soon as a positive lab result had been documented by the laboratory. Time measurement was stopped once an ICP had been notified. The ascertainment of notification dates was done manually. Before the implementation of the IC workflow, ICP were asked to write down dates as soon as they had been notified of infectious patients. After the workflow had been implemented the date of notification was considered to be the date when an ICP released the automatically created infection alert in Soarian®. Nevertheless, this data was extracted manually out of workflow audit trails, as there was no automated controlling functionality available, yet.

Independent of the measurements of time to notification more data was collected in order to identify how much time was spent while screening paper reports or patient charts. Therefore, ICP were asked to write down hours spent on reading reports and screening patient charts before the implementation of the workflow.

The comparison of pre- and post-metrics reveals that time to notification was reduced by more than 75 % after the workflow had been implemented (cf. Table 2). Time to notification averaged out at 70 hours before the implementation and has reduced to an average of 17 hours after the implementation of the IC workflow. The high number of 17 hours is mainly due to process limitations in matters of personnel capacity, as there is still no ICP available on weekends or night hours. Nevertheless, it is obvious that substituting the old paper reports based IC process for the new workflow supported IC process increased efficiency greatly. Furthermore, ICP spent an average of 30 % of their daily work time on screening infection reports and patient charts. This was decreased to almost zero after the implementation of the workflow, since required patient information is now available instantly through the integration of ICP to Soarian®.

	Time to notification: pre-metrics [hours]	Time to notification: post-metrics [hours]	Difference [hours]
Average (VRE)	150,00	20,67	129,33 (86, 22 %)
Average (CDIFF)	25,68	15,68	10,00 (38,94 %)
Average	69,68	16,99	52,69 (75,61 %)

Table 2. Comparison of post- and pre-measurements

It is important to note, that not only significant quantitative process improvement has been made but also and maybe even more important qualitative improvement has been made. Major improvements to patient safety were made through the implementation of HAI history screening, as every inpatient, now, is screened for a positive history (in the last six month) of infection statements. Furthermore, the process quality has been improved through reducing the risk of human errors, since ICP no longer rely on manually generated paper reports or manually left voicemails. Finally, the implementation of the workflow greatly contributed to the process of getting health workers, especially ICP, online. It was observed that the automated IC process was functioning as incentive to overcome the negative attitude some health workers might have concerning IT in inpatient care (Doolin 2004).

4 Conclusion and Next Steps

In this paper we presented reasons for the inappropriateness of greenfield approaches, like BPR, for the optimization of clinical processes in healthcare. Both on a conceptual and a practical perspective, BPM appeared to provide the desired cost reduction, increase in patient safety and relief for health workers in matters of routine tasks. Furthermore, significant potential for automating coordination and evaluation task (e.g. calling floors, screen charts) was discovered, utilized and in consequence contributed to patient safety, too.

As revealed by the process analysis, the implementation of the new workflow supported IC process greatly increased efficiency and patient safety. However, the average time to notification of 17 hours is still high. This is mainly due to the two facts: First, ICP do not work during night hours or on weekends. Second, ICP are not signed on to Soarian® continuously during work hours, as they need to be on the floor as well.

A simple solution to uncouple ICP from being continuously signed-on is to use pagers, cell phones or even personal digital assistants (PDA) to notify ICP of infectious patients. This could be used in addition to the worklist of Soarian®. An additional possibility to further decrease the time to notification is the implementation and delegation of on-call duties for ICP once paging, for instance, was implemented. ICP could take their pagers home and perform simple follow up task over the phone while working from home.

We see additional space for process improvement in integrating more actors to the IC process. By now, the laboratory still needs to call the floor directly. This process could be handled by an extended IC workflow, which would automatically notify nurse stations through pagers, PDA or tablet computers. Other follow-up tasks could be integrated, like reminding the floor to put the patient in isolation after a given amount of time or escalating the order for isolation to the designated physicians. Extending the workflow to more and more participants of the IC process could, finally, result in a companywide standardized automated IC process. On a more comprehensive approach, even digital door plates could be used to indicate isolation of infectious patients at the entry of every room. In doing so, the implementation IC workflow could actively reduce the risk of infection of non-clinical actors like visitors or other patients.

References

- Becker, J., Kugeler, M., and Rosemann, M. (eds.) *Process Management: A Guide for the Design of Business Processes*, 2nd Edition, Springer, Berlin, 2007. To appear.
- Borst, F., Appel, R., Baud, R., Ligier, Y., and Scherrer, J.R. "Happy birthday DIOGENE: a hospital information system born 20 years ago," *International Journal of Medical Informatics* (54:3), 1999, pp. 157-167.
- Burke, J.P. "Infection Control - A Problem for Patient Safety," *New England Journal of Medicine* (348:7), 2003, pp. 651-656.
- Centers for Disease Control and Prevention (CDC) "National Nosocomial Infections Surveillance (NNIS) System Report, data summary from January 1992 through June 2004, issued October 2004," *American Journal of Infection Control* (32:8), 2004, pp. 470-485.
- Davenport, T. *Process Innovation: Reengineering Work Through Information Technology*, Harvard Business School Press, Boston, 1993.
- DiMasi, J.A., Hansen, R.W., and Grabowski, H.G. "The price of innovation: new estimates of drug development costs," *Journal of Health Economics* (22:2), 2003, pp. 151-185.
- Doolin, B. "Power and resistance in the implementation of a medical management information system," *Information Systems Journal* (14:4), 2004, pp. 343-362.
- Gardner, R.M., Pryor, T.A., and Warner, H.R. "The HELP hospital information system: update 1998," *International Journal of Medical Informatics* (54:3), 1999, pp. 169-182.
- Hammer, M., and Champy, J. *Reengineering the Corporation - A manifesto for business revolution*, HarperBusiness, New York, 1993.
- Harmon, P. *Business Process Change - A Manager's Guide to Improving, Redesigning, and Automating Processes*, Morgan Kaufmann Publishers, San Francisco, 2003.
- Health Level Seven "Health Level Seven Implementation Support Guide for HL7 Standard Version 2.3," 1998, <http://hl7.org/Special/IG/final.pdf>.
- Health Level Seven "Arden Syntax for Medical Logic Systems, Version 2.5," 2005, <http://www.hl7.org/>, 2007-03-03.
- Institute of Medicine *Crossing the quality chasm: A New Health System for the 21st Century*, National Academies Press, Washington, D.C., 2001.
- Johansson, H.J., McHugh, P., Pendlebury, A.H., and Wheeler, W.A. *Business Process Reengineering - Breakpoint Strategies for Market Dominance*, Hohn Wiley & Sohns Ltd, Chichester, 1993.

- Kohn, L.T., Corrigan, J.M., and Donaldson, M.S. (eds.) *To Err is Human: Building a Safer Health System*, National Academy Press, Washington, D.C., 2000.
- Lenz, R., and Reichert, M. "IT Support for Healthcare processes," *Proceedings of the 3rd International Conference on Business Process Management (BPM 2005)*, W. M. P. van der Aalst, B. Benatallah, F. Casati and F. Curbera (eds.), 2005, pp. 354-363.
- Magruder, C., Burke, M., Hann, N.E., and Ludovic, J.A. "Using Information Technology to Improve the Public Health System," *Journal of Public Health Management and Practice* (11:5), 2005, pp. 123-130.
- Mast, P., Ochs, U., Loewe, W., and Weise, K. "Aktueller Stand in der Fallkostenabrechnung nach DRG: Sicht des Finanzcontrollers," *Trauma und Berufskrankheit* (6:Supplement 1 May), 2004, pp. 95-96.
- Object Management Group "Business Process Modeling Notation (BPMN) Specification 1.0," 2006, <http://www.omg.org/cgi-bin/apps/doc?dtc/06-02-01.pdf>.
- Organisation for Economic Cooperation and Development "OECD Health Data 2006: How Does the United States Compare," 2006, <http://www.oecd.org/dataoecd/29/52/36960035.pdf>, 2007-02-04.
- Panzarasa, S., and Stefanelli, M. "Workflow management systems for guideline implementation," *Neurological Sciences* (27:Supplemental 3), 2006, pp. 245-249.
- Porter, M.E. *Competitive Advantage: Creating and Sustaining superior Performance*, The Free Press, New York, 1985.
- Pryor, T.A., and Hripcsak, G. "The arden syntax for medical logic modules," *International Journal of Clinical Monitoring and Computing* (10:4), 1993, pp. 215-224.
- Scheer, A.-W. *ARIS – Business Process Modelling*, 3rd Edition, Springer, Berlin, 2000.
- Shwe, M., Sujansky, W., and Middleton, B. "Reuse of Knowledge Represented in the Arden Syntax," *Proceedings of the Annual Symposium on Computer Applications in Medical Care*, 1993, pp. 47-51.
- Siemens AG "Soarian@," 2007, http://www.medical.siemens.com/webapp/wcs/stores/servlet/CategoryDisplay~q_catalogId~e_-1~a_categoryId~e_1007195~a_catTree~e_100001,1007111,1007092,1007065,1007195~a_langId~e_-1~a_storeId~e_10001.htm, 2007-03-03.
- Teich, J.M., Glaser, J.P., Beckley, R.F., Aranow, M., Bates, D.W., Kuperman, G.J., Ward, M.E., and Spurr, C.D. "The Brigham integrated computing system (BICS): advanced clinical systems in an academic hospital environment," *International Journal of Medical Informatics* (54:3), 1999, pp. 197-208.
- The Medical Letter Inc. "Choice of Antibacterial Drugs," *Treatment Guidelines from The Medical Letter* (2:19), 2004, pp. 13-26.
- The Medical Letter Inc. "Treatment of Clostridium difficile-Associated Disease (CDAD)," *The Medical Letter on Drugs and Therapeutics* (48:1247), 2006, pp. 89-90.
- van der Aalst, W.M.P., ter Hofstede, A.H.M., and Weske, M. "Business Process Management: A Survey," *Proceedings of the 1st International Conference on Business Process Management (BPM 2003)*, W. M. P. van der Aalst, A. H. M. ter Hofstede and M. Weske (eds.), 2003, pp. 1-12.
- Weber, S.G., Huang, S.S., Oriola, S., Huskins, W.C., Noskin, G.A., Harriman, K., Olmsted, R.N., Bonten, M., Lundstrom, T., Climo, M.W., Roghmann, M.-C., Murphy, C.L., and Karchmer, T.B. "Legislative Mandates for Use of Active Surveillance Cultures to Screen for Methicillin-Resistant Staphylococcus aureus and Vancomycin-Resistant Enterococci: Position Statement From the Joint SHEA and APIC Task Force," *Infection Control and Hospital Epidemiology* (28:3), 2007, pp. 249-260.
- Wisniewski, M.F., Kieszowski, P., Zagorski, B.M., Trick, W.E., Sommers, M., and Weinstein, R.A. "Development of a Clinical Data Warehouse for Hospital Infection Control," *Journal of the American Medical Informatics Association* (10:5), 2003, pp. 454-462.