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Assessment of hospital processes using a process mining technique: Outpatient process analysis at a tertiary hospital

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ABSTRACT

Introduction: Many hospitals are increasing their efforts to improve processes because processes play an important role in enhancing work efficiency and reducing costs. However, to date, a quantitative tool has not been available to examine the before and after effects of processes and environmental changes, other than the use of indirect indicators, such as mortality rate and readmission rate.
Methods: This study used process mining technology to analyze process changes based on changes in the hospital environment, such as the construction of a new building, and to measure the effects of environmental changes in terms of consultation wait time, time spent per task, and outpatient care processes. Using process mining technology, electronic health record (EHR) log data of outpatient care before and after constructing a new building were analyzed, and the effectiveness of the technology in terms of the process was evaluated.
Results: Using the process mining technique, we found that the total time spent in outpatient care did not increase significantly compared to that before the construction of a new building, considering that the number of outpatients increased, and the consultation wait time decreased. These results suggest that the operation of the outpatient clinic was effective after changes were implemented in the hospital environment. We further identified improvements in processes using the process mining technique, thereby demonstrating the usefulness of this technique for analyzing complex hospital processes at a low cost.
Conclusion: This study confirmed the effectiveness of process mining technology at an actual hospital site. In future studies, the use of process mining technology will be expanded by applying this approach to a larger variety of process change situations.

1. Introduction

The processes of many organizations play an important role in advancing the performance and efficiency of work [1]. The organization must constantly improve processes to gain competency. First, the process must be understood, and one such tool for understanding the process is process mining technology [2]. Process mining refers to the analysis of the process log or data corresponding to the process of a business and extracting the required information [3,20]. Process mining technology consists of three main types—discovery, conformance, and enhancement [1,2,4,8,11,18]. That is, process mining is not only capable of discovering process models but also of identifying deviations between models and log, and of conducting performance analyses [1,16]. Process mining allows for the extraction of necessary information related to the process and allows one to derive, monitor, and improve the actual process [4]. Because process mining technology analyzes the log, which is already in the form of data, it can save time and reduce the costs of data collection. In addition, process mining technology only analyzes recorded data, which prevents distortion of information and ensures accuracy and objectiveness [1,5,6,15].

In hospital settings, clinical and administrative data have been computerized with the introduction of electronic health records (EHR) systems to improve the quality of medical care [7,21,22]. Such systems consist of a wide range of applications that record events [8], which further expand the opportunities for applying

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process mining technology in the field of medicine. Hospitals with these data apply a care system that is based on the process, which allows for the selection of medical services based on patients' conditions [9]. This approach improves the patient care and quality of care, thus underscoring the importance of the role of the process [10,19,23]. However, standardizing such processes in hospitals is not easy, and discovering problems and implementing improvements remain challenging. Limitations include a lack of new research in this area, an inability to apply a formal process flow due to large discrepancies across individual patients and hospital organizations, and difficulties in identifying the types of health care processes that occur even in a group of patients with the same diagnosis due to numerous diverging factors [11]. In addition, a data-based, automated tool for evaluating hospital process changes after improvements are made is currently lacking [12], and therefore the quality of health care delivery can only be evaluated based on indirect clinical indicators, such as mortality and readmission rates [9,10]. One previous study that analyzed the treatment process of stroke patients [8] and another that assessed the treatment process of female oncology patients [11] used process mining technology to analyze a complex process, such as that of a hospital, and confirmed the applicability of the technology. However, these previous studies have not devised the strategies to apply and assess the results of the process mining in the actual hospital sites. In our previous study, we compared an expert-driven outpatient care process with a machine-driven process using a process mining technique and measured task-based performance [13]. However, we did not evaluate the performance in relation to changes in the hospital environment or the achieved process.

In this study, we used process mining technology to analyze process changes based on changes in the environment and the effects of the changes in terms of the consultation wait time, the amount of time required for each step, and the total outpatient care process. This approach was used to assess the applicability of process mining technology as an objective tool for hospital process evaluation and study the effectiveness of the technology at a real medical site.

2. Methods

2.1. Materials

The study site, Seoul National University Bundang Hospital, is a tertiary hospital in South Korea that includes 1400 beds and 38 operating rooms. The hospital was established in May of 2003 and has been operating as a fully digital hospital since its establishment. In April of 2013, the hospital opened a new building that was annexed to the original building and updated the emergency room, intensive care unit, cancer center, and clinical neuroscience center to accommodate the new space. The new building houses the emergency room, intensive care unit, comprehensive cancer center, and clinical neuroscience center to increase collaboration among departments and the efficiency of treating patients with severe, rare, or incurable diseases. After the inception of the new building, the cancer center moved from the second floor of the original building to the second floor of the new building, and the clinical neuroscience center moved from the first floor of the original building to the second floor of the new building. Moreover, additional administrative and register counters were installed in the new building. A room dedicated to anti-carcinogenic serum injection was established on the fifth floor of the new building, and outpatients of the cancer center were able to receive the injection service in the new building. To evaluate the effectiveness of the changes in the hospital facility environment before and after the establishment of the new building in terms of the process, we selected the EHR log data of the outpatient clinics at the new building, such as the cancer and clinical neuroscience centers, as the analysis object, where there have been changes in the outpatient care environment due to the establishment of the new building. We collected one month of data prior to the establishment of the new building in July of 2012 and one month of data after the establishment of the new building in July of 2013. Since most of indexes regarding the evaluation of care processes are measured per month or day, data for a month is used.

2.2. Event log collection and pre-processing

We defined the event log of the outpatient care process as shown in Table 1. We collected the activity completion time, the corresponding department, and the related detail information for all the outpatient care activities that are performed when patients visit our hospital. However, regarding treatment events, we collected the treatment start date rather than the treatment completion date because the system did not have information regarding the activity completion time. We assumed that the treatment event would be inserted in the last stage of all processes. Since we have to identify case ID in the analysis to separate events according to patients, the anonymized patient ID is generated for each patient. Instead of the anonymized ID, any personal information such as social security

Table 1
Types and attributes of event logs for analyzing outpatient care processes.

Event type (activity)	Attribute
Sign on selective medical service	Case ID, Activity completion time, Resource ID, Resource department code
Referral registration	Case ID, Activity completion time, Resource ID, Resource department code
Outside image registration	Case ID, Activity completion time, Resource ID, Resource department code
Payment	Case ID, Activity completion time, Resource ID, Resource department code
Test registration	Case ID, Activity completion time, Resource ID, Resource department code, Test code, Type of test, Scheduled test date
Test	Case ID, Activity completion time, Resource ID, Resource department code, Test code, Type of test, Scheduled test date
Consultation registration	Case ID, Activity completion time, Resource ID, Resource department code, Patient type, Department code, Appointment method, Appointment Date
Consultation	Case ID, Activity completion time, Resource ID, Resource Department code, Patient type, Department code, Appointment method, Appointment Date
Consultation scheduling	Case ID, Activity completion time, Resource ID, Resource department code, Patient type, Practitioner ID, Scheduled department code, Scheduled consultation date
Test scheduling	Case ID, Activity completion time, Resource ID, Resource department code, Test code, Type of test, Scheduled test date
Admission scheduling	Case ID, Activity completion time, Resource ID, Resource department code
Outside-hospital prescription printing	Case ID, Activity completion time, Resource ID
In-hospital prescription receiving	Case ID, Activity completion time, Resource ID, Resource department code
Certificate issuing	Case ID, Activity completion time, Resource ID, Resource department code
Treatment	Case ID, Treatment start date, Resource ID, Resource department code, Treatment code

Case ID: a unique ID for identification of outpatients of the day, Resource ID: a unique ID for identification of someone or something that performed the specific activity, Resource department code: a unique code for identification of the resource ID's departments.