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Evaluating waiting time with real-world health information in a high-volume cancer center

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Abstract

Wait time and scheduling for outpatient chemotherapy administration depends on various factors including infusion room hours of operation, availability of oncologists, nursing and pharmacy staffing, and physical space limitations. The aim of this study was to use the electronic event log of patients on health information system (HIS) to map and analyze patient flow in advanced metastatic colorectal patients at an academic cancer center. From January 2009 to December 2014, patients who were diagnosed with metastatic colorectal cancer and received outpatient chemotherapy confined to FOLFIRI (fluorouracil, leucovorin, and irinotecan) or FOLFOX (folinic acid, fluorouracil, and oxaliplatin) were identified. From the HIS, patient flow was mapped by collection of event records including blood collection and pretreatment laboratory test, arrival to outpatient clinics, outpatient session (interview, drug accountability and appointment scheduling), and initiation of chemotherapy. A total of 10,638 patients were analyzed for 136,281 outpatient visits. The total office stay time from outpatient registration to initiation of chemotherapy was 92.58 ± 87.96 (mean $\pm$ standard deviation) minutes. Each outpatient session lasted 23.75 ± 51.55 minutes. After completing the outpatient session, patients waited $1,657.23 \pm 3,027.65$ minutes before chemotherapy and 46.66 ± 75.94 minutes within infusion room. Compared to the prior first come first serve rule, the new reservation system showed an improvement in overall waiting time from $2,432.3 \pm 4,822.9$ to $2,386.7 \pm 143.4$ minutes; however, waiting time within infusion room slightly increased from 36.68 ± 49.33 to 48.13 ± 46.32 minutes. Our findings indicate that transaction data analytics from HIS can be used to evaluate patient flow within oncology outpatient practice based on real-world hospital data.

Abbreviations: FOLFIRI = fluorouracil, leucovorin, and irinotecan, FOLFOX = folinic acid, fluorouracil, and oxaliplatin, HIS = Health Information System.

Keywords: colorectal neoplasms, hospital transaction data, patient flow, process refinement, real-world data

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1. Introduction

The care of cancer patients involves multiple departments within the hospital at various levels.[1] Due to the complexity, the flow between office visits to infusion units is essential for adequate delivery of care throughout the system. Delays within this flow are major sources of overall dissatisfaction among patients and health care providers.[2,3]

Asan Medical Center (AMC) is the largest medical institute in Korea and attends to 10,000 outpatients per day. The chemotherapy day unit is a 119-chair unit, dedicated to delivering systemic anticancer treatments to day-admitted patients, currently provides upward of 1000 treatment episodes per month. Everyday patients experience multiple checkpoints before receiving chemotherapy. Therefore, the importance of incorporating both clinical and administrative data across departments is essential to increase efficiency in the delivery of health care services.

AMC has developed integrated healthcare information system (HIS) through the Asan Medical Information System built in-house by our medical information-development team.[4] Asan Medical Information System includes order communication system including computerized physician order entry system, picture archiving communication system (PACS), electronic medical record system, laboratory electronic blood-tracking information system, pharmacy and Asan BiomedicaL research Environment, the Asan clinical research data warehouse. AMC

has also developed an Integrated Patient Monitoring System. Four monitoring systems are operative; these allow integration of inpatient bed management, an outpatient wait scheduling system, an operation theater management process system, and an integrated laboratory reservation monitoring system. However, despite these efforts, office waiting time is still an issue.

It is difficult to objectively measure time delays in real-world practice because of the variation in clinical scenario of each visit between and within each patient. In this retrospective analysis, we propose using hospital transaction data to measure patient time and map patient flow within the office and infusion room. Specifically, we describe the architectural framework and descriptive analytics from a high-volume cancer center. We also assess the real-world impact of quality improvement efforts within scheduling infusions on office waiting times. To decrease the variation associated with different cancer types, we confined our evaluation to metastatic colorectal cancer patients who were receiving either first or second-line FOLFOX or FOLFIRI chemotherapy. As targeted agents including bevacizumab and antiepidermal growth factor receptor (EGFR) therapy were not reimbursed until 2014, regimens containing these agents were not included. To our knowledge, this is the first study that uses a combination of health administrative and clinical data to map patient and workflow based on real-time hospital data.

2. Materials and Methods

2.1. Patients and operational flow

The data were extracted from deidentified clinical data warehouse.[5] Patients who were diagnosed with metastatic colorectal cancer and received first or second-line chemotherapy consisting of FOLFOX (oxaliplatin 85 mg/m^2 intravenously over 2 hours + leucovorin 400 mg/m^2 intravenously over 2 hours, followed by 5-FU 400 mg/m^2 intravenous bolus, followed by 5-FU 2,400 mg/m^2/d intravenously as a 46-hour continuous infusion every 2 weeks) or FOLIRI (irinotecan 150 or 180 mg/m^2 intravenously over 90 minutes + leucovorin 400 mg/m^2 intravenously over 2 hours, followed by 5-FU 400 mg/m^2 intravenous bolus, followed by 5-FU 2,400 mg/m^2/d intravenouly as a 46-hour continuous infusion every 2 weeks) at the outpatient office between January 2009 to December 2014 were extracted to the total number of patients was 11,220, and these patients visited 193,401 times. As targeted agents including bevacizumab and anti-EGFR therapy were not reimbursed only a selected number of patients received regimen including these agents and were excluded from this analysis. Therefore, 10,368 patients who visited 136,281 times were included in this study.

Current operational and clinical processes were identified, and the workflow was examined (Supplement Fig. 1 http://links.lww.com/MD/E926). Patients undergo blood collection 2 hours prior to the appointment time, after which they would register at the outpatient office, and vital parameters are taken at the triage/waiting area. Patients enter the office room and begin outpatient sessions (medical interview, drug accountability, and appointment scheduling). Chemotherapy orders are then submitted to the pharmacy real-time via computerized physician order entry system, and patients proceed to the chemotherapy day unit and wait for drug preparation and initiation of parenteral chemotherapy (FOLFOX or FOLFIRI). After bolus 5-FU and oxaliplatin or irinotecan administration, the patient receives

infusional 5-FU via an implantable central venous port system and ends the visit. All activities occur within a single building.

Each treatment visit was mapped into the following steps that had digital log time points within the data warehouse: blood collection and reporting for pretreatment laboratory test, arrival to outpatient registration, outpatient session (medical interview, drug accountability and appointment scheduling), and initiation of chemotherapy (Supplement Fig. 1 http://links.lww.com/MD/E926). The following definitions were used: total office stay time as the time between registration and end of session; office waiting time as the time between registration and start of session; infusion room waiting time as the time between end of session and initiation of chemotherapy infusion.

2.2. Data collection

The collected data were reconstructed based on event-driven patient-tracking approach. Event-driven patient-tracking approach is to track patients by deducing their location through changes in their last known status. Most data from HIS can be used as source data to reproduce patient flow, for instance, when the patient receive computed tomography scanning the time log is made within picture archiving communication system without any manual efforts. When a patient has moved from outpatient waiting room to doctor's office, this data is recorded at management of electronic display board which is a submodule of our HIS.

Two data sets were collected in this study for event-driven patient tracking. First, data from January 2009 to December 2014, this data was collected to determine the overall waiting time for outpatient chemotherapy patients. Secondly, data from January 2013 to December 2017 were collected to analyze the effects of changing the reservation systems in infusion room. In May 2014, the infusion room appointments were changed from a first come, first served basis to a reservation system. To evaluate the effects of the reservation system, data from January 2013 to February 2014 and from May 2014 to December 2017 were grouped separately and termed as pre and postinitiative, respectively. Two months between the pre and postinitiative periods were excluded from the test period after the introduction of the reservation system.

2.3. Statistical analysis

All data were based on descriptive analysis. Time points for blood collection and reporting for pretreatment laboratory test, arrival to outpatient registration, outpatient session (medical interview, drug accountability, and appointment scheduling), and initiation of chemotherapy were obtained. Intervals between time points were analyzed. Time dependency was evaluated with hours within a day, days within a week, and months within a year. The comparative evaluation of pre and postinitiatives in the infusion room was conducted using a t test for the following 2 aspects: the difference in waiting time before the patient arrived at the infusion room, and the waiting time within the infusion room.

Segmented regression is an analytical method that examines the difference between before and after trends and gaps when there is an intervention during the study period, and especially examines the effect of intervention.[6] In this paper, we use the SAS 9.4 version of the PROC AUTOREG procedure to take into account the autocorrelation of the mean waiting time in infusion room.[7] The number of patients at each time point was used as a

calibration variable. All reported *P* values were 2-sided, and *P* < .05 was considered significant. SAS version 9.4 and R software (ver. 3.3, http://cran.r-project.org/) was used for the statistical analyses.

2.4. Ethical statement

This study was approved by the institutional review board of the hospital (IRB no. 2015-1379). The need for informed consent was waived by the ethics committee, as this study utilized routinely collected log data that were anonymously managed at all stages, including data cleaning and statistical analyses.

3. Results

Between January 2009 to December 2014, a total of 10,638 patients were analyzed for 136,281 outpatient visits. Table 1 shows the total number of patients, total visit, age, sex, and number of visits per year. Overall, the number of patients and visits is increasing year by year. Age, sex, and number of visits are the same for each year.

3.1. Waiting time

We visualized the process of receiving the patient's treatment in the hospital as shown in Figure 1. The time taken before and during each process is shown in Figure 1 as the mean, standard deviation and median. Out of a total of 10,638 patients, 7682 patients underwent baseline blood sample and test prior to outpatient registration and the time taken for this process was 57.66 ± 92.93 (mean ± standard deviation) minutes (median, 46). A total of 10,368 outpatient registered patients underwent an outpatient session. After outpatient registration, the total office stay time taken registration to outpatient session was 92.58 ± 87.96 (median, 73), office waiting time was 68.84 ± 70.75 (median, 55), and session time was 23.75 ± 51.55 minutes (median, 8). A total of 6027 patients out of 10,638 patients received chemotherapy after the outpatient session; the rest of the patients received inpatient chemotherapy after admission. After termination of the outpatient session, the patient's infusion room waiting time (time interval between leaving the outpatient area to enter the infusion room) was 1657.23 ± 3027.65 minutes (median, 112) and within infusion room waiting time (time interval between entering the infusion room to receiving chemotherapy) was 46.66 ± 75.94 minutes (median, 26).

3.2. Analysis pre- and postenforcement of reservation system for infusion room

We conducted an analysis of patient waiting time differences with the introduction of reservation system for infusion room appointments. The preinitiative (from January 2013 to February 2014) included 2002 patients with a total of 16,149 visits. The postinitiative (from May 2014 to December 2017) included 5564 patients with a total of 45,740 visits. A comparative analysis showed an improvement in overall waiting time with the new reservation system from 2432.3 ± 4822.9 (median, 80) to $2386.7 \pm 5,143.4$ (median, 103) minutes, although the variance in waiting time increased. The waiting time within the infusion room increased from 36.68 ± 49.33 (median, 25) to 48.13 ± 46.32 (median, 32) minutes, while the variance decreased.

Time-series analysis of total infusion room waiting time showed a downward-level break after introduction of the infusion room reservation system ($P = .359$) (Fig. 2A). Right after the introduction of the reservation system, the estimated mean for waiting time of infusion room dropped abruptly by 80.113 minutes per month. Interestingly, waiting time showed an upward trend (P value for baseline trend = .019) before the introduction of the system, but a marked downward trend after (P value for trend change = .026). Right after the introduction of the reservation system, the estimated mean waiting time of within infusion room statistically significant increased abruptly by 15.949 minutes per month ($P \le .001$) (Fig. 2B). There was no significant month-to-month change in the mean waiting time of within infusion room pre- and postinitiative, respectively ($P = .66$ and $P = .691$). The light blue shading in Figure 2 represents the monthly confidence interval.

Table 1

Baseline demographics.

	Year					
	2009	**2010**	**2011**	**2012**	**2013**	**2014**
No. of patients	2965	3474	4262	4711	4741	5135
No. of visits	16,744	18,219	22,263	26,433	24,797	27,825
Age						
Mean ± SD	58.10 ± 10.72	58.09 ± 10.66	58.50 ± 10.72	59.23 ± 10.81	59.37 ± 11.03	59.10 ± 11.08
(median)	(59)	(58)	(59)	(59)	(59)	(59)
Sex						
Male	1819 (61.3)	2126 (61.2)	2642 (62.0)	2924 (62.1)	2858 (60.3)	3106 (60.5)
Female	1146 (38.7)	1348 (38.8)	1620 (38.0)	1787 (37.9)	1883 (39.7)	2029 (39.5)
Visit number						
1	772 (26.0)	957 (27.5)	1194 (28.0)	1.249 (26.5)	1249 (26.3)	1383 (26.9)
2–10	1697 (57.2)	2003 (57.7)	2422 (56.8)	2.611 (55.4)	2754 (58.1)	2882 (56.1)
10–30	482 (16.3)	502 (14.5)	635 (14.9)	840 (17.8)	732 (15.4)	849 (16.5)
>30	14 (0.5)	12 (0.3)	11 (0.3)	11 (0.2)	6 (0.1)	21 (0.4)
Total infusion room waiting time, min	1992.8 ± 3144.2	1617 ± 3046.4	1620.3 ± 2867	1681.5 ± 3049.9	1749 ± 3270.4	1449.7 ± 2833.8
Mean ± SD (median)	(181.5)	(115)	(120)	(119)	(116)	(83)

Values are presented as number (%) unless otherwise indicated.
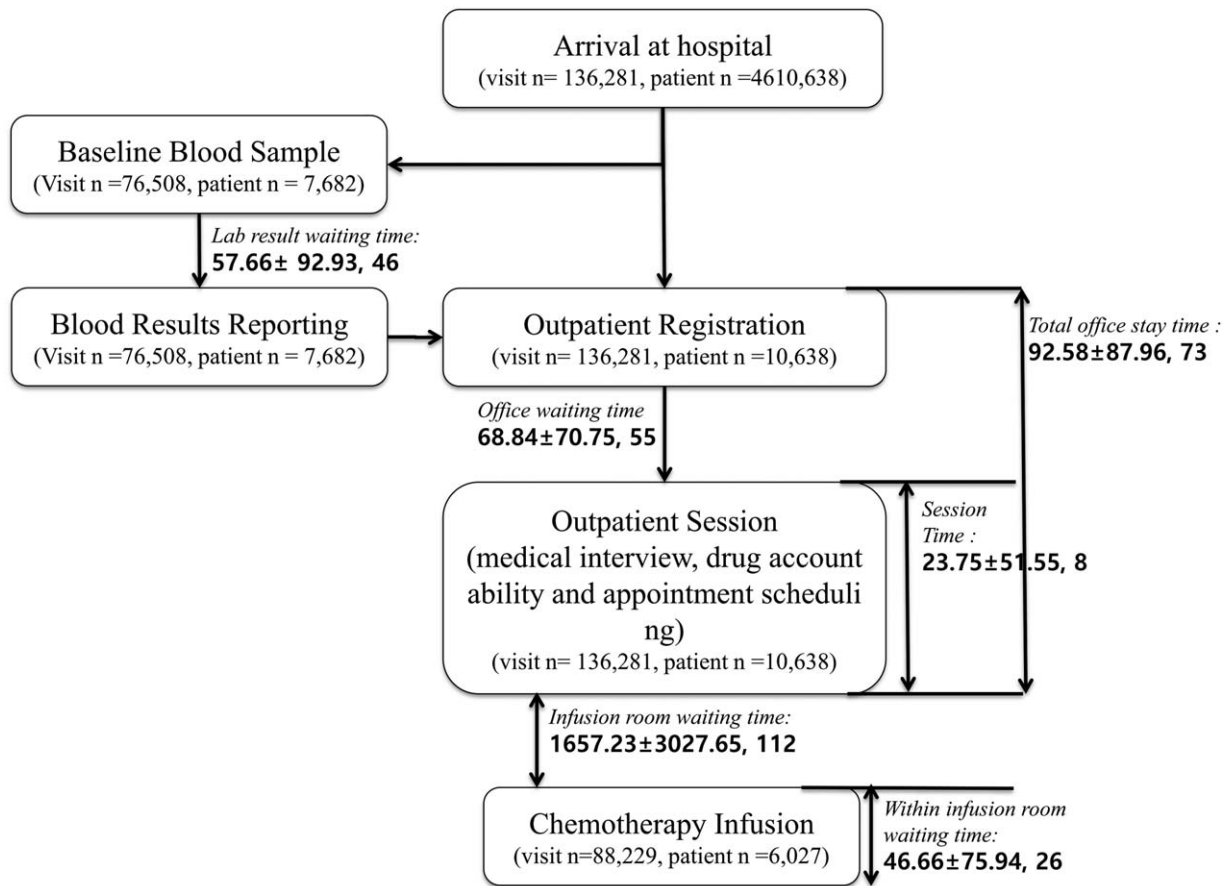SD = standard deviation.

Figure 1. Diagram of waiting time by typical patient flow process in patients with outpatient chemotherapy.

4. Discussion

Office waiting is around 2 hours and variability related to patients waiting in the office and infusion room is large, which leads to frustration between patients and care providers. By intervening the scheduling process of chemotherapy infusions, waiting time from the outpatient area to actual infusion decreased. This hospital transaction data analysis based on health information systems and electronic health records data has allowed us to
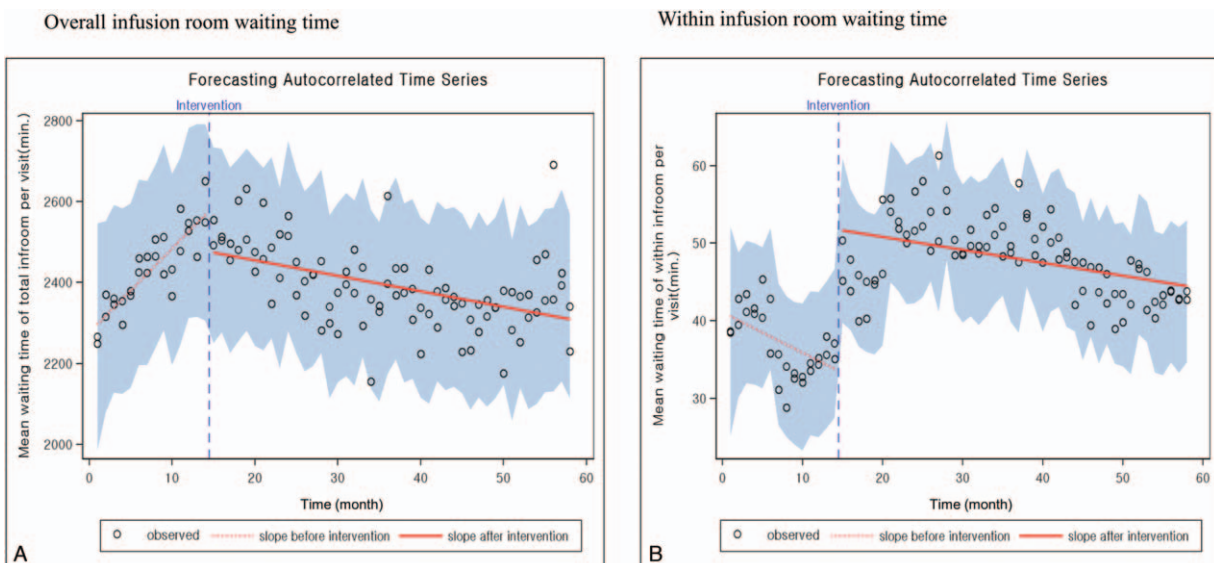

Figure 2. Changes in (A) overall and (B) within infusion room waiting time according to the use of reservation system.

capture real-world practice and assess impacts of interventions directed to clinical operations.

Waiting time has been a long-standing issue within medicine. Patient waiting time is one of the indicators for measuring the quality of healthcare offered by the hospital,[8] long wait times are a barrier to receiving medical services [9] and negatively affects patient satisfaction of healthcare.[10–12] It has been divided into 2 categories; one has been the time from patient referral to the time patients actually see specialist and another the actual time patient's wait and stay within the clinic. We have chosen to approach the later because all the data was accessible within a single institutional data warehouse by integrating administrative and clinical informatics extracted from the health information system. Improving access to outpatient treatment units has been approached by flow analysis in various institutes in endeavors to improve patient care.[13,14] As cancer patient care involves various departments including outpatient clinic, radiology, pharmacy, laboratory services, and the oncology treatment facility, it is a complicated flow with various steps.[2,15] Woodall et al[16] have modeled the patient flow at Duke Cancer Institute and have shown that nurse unavailability during oncology treatment caused a serious bottleneck in patient flow based on simulation. Others have also utilized discrete event simulation to analyze the patient flow and find measures to lessen patient waiting time at cancer chemotherapy units. These simulation studies analyze the process, collect data, build scenarios, and run simulations.[17] While these studies build strong models, they can be limited by various factors. Models are built on data collected from limited numbers of patients, which may not reflect the real world. In addition, although models are built meticulously, the impacts of interventions are limited to simulation data.[18]

We collected data by integrating health data including administrative and clinical informatics to reconstruct patient flow based on event-driven patient-tracking approach.[19] Patient flow was tracked by deducing their location through changes in their last known status. Previously, patient flow analysis and chemotherapy scheduling studies were based on methods that tag patients with tracking tools or use extra personals to follow patients to analyze patient flow.[20,21] However, because of limited resources, evaluation was confined to limited periods and patients that would lead to results that would be directly used in everyday practice. Event-driven patient-tracking approach has allowed us to connect administrative and clinical informatics to achieve quality improvements, increase patient access and cost controls by assessing interventional impacts with real-world data. In addition, real-world data allowed us to identify unexpected findings. One notable finding was that the waiting time within the infusion room slightly increased (from 36.68 ± 49.33 [median, 25] to 48.13 ± 46.32 [median, 32] minutes) compared to the waiting time in the infusion room (from $2,432.3 \pm 4,822.9$ [median, 80] to $2,386.7 \pm 5,143.4$ [median, 103] minutes). This result can be confirmed in segmented regression analysis. Through segmented regression analysis, we found a decrease in the waiting time of infusion room after introducing the reservation system ($P = .003$). This analysis showed that the infusion room waiting time was increased continuously before the introduction of the reservation system ($P = .019$), but it decreased significantly after the introduction of the reservation system ($P = .026$). On the contrary, waiting time of within infusion room increased significantly ($P < .001$). After interviewing the workforce, we found that this was related to the fact that prescheduling was less flexible than first come, first serve that led

to delays during crowded periods. This was related to the fact that resource was allocated according to the prescheduled number of patients, which led to insufficient resource in crowded periods despite prescheduling because of overcrowding itself. Detrimental effects of this overcrowding effect are often reported seen in delays of procedures within the emergency department.[22,23] While the overcrowding associated with the emergency room is usually related to variations in input of patients, the overcrowding observed in this study was related to overbooking. Some have reported that overbooking can improve insufficient patient access by compensating no-shows; however, more studies are required to define the optimal setting of overbooking.[24–26]

Although we have shown that impacts of quality improvement interventions can be captured with real-world data, there are various limitations. As the data was confined to those that could be extracted from the warehouse, it could not capture everyday practice completely. For example, the presence of caregivers, number of patients with other indications besides colorectal cancer arriving at the clinic and chemotherapy unit, and workforce variability are just some of factors. The quantity and quality of each visit also is very important, that is visits that include disease response evaluation and complications would take longer and increase variability. However, as these factors would be random due to the large number of patients, the significance of interventional changes can still be assessed. Through this study we have also explored many aspects to improve on. For example, nurses within the clinic help patients understand many points that took place within the office after physicians have seen the patients; however, this could not be captured. As this study was performed on data collected over 5 years, there can be some confounding factors over that period. However, except for the change in chemotherapy scheduling, there were no changes in the treatment process or regimens.

We conclude that health information-based data warehouses can help hospitals understand the patient flow and provide data-driven assessments of quality improvement measures. We hope that these practices will lessen the patients' frustrations related to operational inefficiencies.

Author contributions

Conceptualization: Yu Rang Park, Kyu-pyo Kim, Jeong-Eun Kim, Yong Sang Hong.
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Writing – review & editing: Yu Rang Park, Jeong-Eun Kim, Yong Sang Hong, Tae Won Kim.

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