Evaluating Different Strategies on the Blood Collection Counter Settings to Improve Patient Waiting Time in Outpatient Units

**Chih-Hao Chen, MS[1], Yao-Te Tsai, PhD[2], Chun-An Chou, PhD[3], Shao-Jen Weng, PhD[1] ⓘ,
Wen-Chin Lee, MD, PhD[4], Li-Wei Hsiao, MD[5], Natan Derek, PhD[1], and Chang-Pu Ko, MS[7]**

Abstract
Long patient waiting time is one of the major problems in the healthcare system and it would decrease patient satisfaction. Previous studies usually investigated how to improve the treatment flow in order to reduce patient waiting time or length of stay. The studies on blood collection counters have received less attention. Therefore, the objective of this study is to reduce the patient waiting time at outpatient clinics for metabolism and nephrology outpatients. A discrete-event simulation is used to analyze the four different strategies for blood collection counter resource allocation. Through analyzing four different strategic settings, the experimental results revealed that the maximum number of patients waiting before the outpatient clinics was reduced from 41 to 33 (20%); the maximum patient waiti-ng time at the outpatient clinics was decreased from 201.6 minutes to 83 minutes (59%). In this study, we found that adjusting the settings of blood collection counters would be beneficial. Assigning one exclusive blood collection counter from 8 to 10 AM is the most suitable option with the least impact on the operational process for hospital staff. The results provide managerial insight regarding the cost-effective strategy selection for the hospital operational strategy.

Keywords
outpatient clinics, process improvement, simulation, patient flows, waiting time

[1]Department of Industrial Engineering and Enterprise Information, Tunghai University, Taichung, Taiwan
[2]Department of International Business, Feng Chia University, Taichung, Taiwan
[3]Department of Mechanical and Industrial Engineering, Northeastern University, Boston, MA, USA
[4]Division of Nephrology, Department of Internal Medicine, Chang Bing Show Chwan Memorial Hospital, Changhua, Taiwan
[5]Division of Endocrinology and Metabolism, Department of Internal Medicine, Chang Bing Show Chwan Memorial Hospital, Changhua, Taiwan
[6]Department of Neuromedicine and Movement Science, Faculty of Medicine and Health Sciences, NTNU-Norwegian University of Science and Technology, Trondheim, Norway
[7]Department of Industrial Engineering and Systems Management, Feng Chia University, Taichung, Taiwan

Corresponding Authors:
Shao-Jen Weng, Department of Industrial Engineering and Enterprise Information, Tunghai University, No. 1727, Section 4, Taiwan Blvd, Xitun District, Taichung 40704, Taiwan.
Email: sjweng@thu.edu.tw

Wen-Chin Lee, Division of Nephrology, Department of Internal Medicine, Chang Bing Show-Chwan Memorial Hospital, No. 6, Lugong Rd, Lukang Township, Changhua 505, Taiwan.
Email: wenchin2010@gmail.com

Highlights

What Do We Already Know About This Topic?

The outpatient units such as metabolism and nephrology in Taiwan usually have long patient waiting times. Previous studies have investigated how to improve the treatment process for reducing patient waiting time.

How Does Your Research Contribute to the Field?

The results of this study highlight the importance of blood collection counter settings which play a remarkable role in patient waiting times.

What Are Your Research's Implications Toward Theory, Practice, or Policy?

The research found that the establishment of an exclusive blood collection counter would reduce the patient waiting time at the outpatient units. It is also proven as a cost-effective strategy that the hospital does not need to invest in more resources.

Introduction

The outpatient unit is one of the major care delivery settings in the healthcare system. It provides services such as medical diagnoses and consultations to patients who are diagnosed with chronic diseases and required for periodic medical follow-ups. As medical and health sciences have advanced significantly, life expectancy has increased over the years.[1] It, therefore, results in larger elderly populations all over the world.[2,3] They become the major source of outpatient demand. In addition, there has been a shift from inpatient care to outpatient care because of newly developed diagnoses, treatments, and monitoring technologies, and most patient care and procedures need to be performed in hospitals.[4] As a result, outpatient clinics are currently facing an overcrowded situation.[5] On the one hand, patients often need to wait longer than usual in the waiting room for doctor appointments, which decreases patient satisfaction.[6] Bielen and Demoulin[7] investigated the relationship between perceived waiting time (more or less than 30 minutes) and waiting time satisfaction. The results showed that longer perceived waiting times reduce satisfaction. Al-Harajin et al[8] reported that when patients wait for more than 20 minutes before consultation, they are more dissatisfied. Bleustein et al[9] also concluded that longer waiting times are negatively associated with patient satisfaction scores. On the other hand, medical staff would have to work overtime or shorten individual consultation times to accommodate increasing outpatient demands, which largely degrades the quality and efficiency of the health care process.

In outpatient clinics, some specialties such as metabolism and nephrology require patients to finish pre-visit examinations such as blood tests and CT/X-ray scans, which could be performed either right before seeing doctors on the same day or a couple of days ahead, such that doctors can deliver more accurate diagnosis based on the patient conditions to date. For instance, in Taiwan's hospitals, it is commonly seen that there is an abundance of outpatients who are required to complete blood tests on the same day for their metabolism and nephrology appointments, compared to other specialty appointments. Thus, overcrowding propagates backward from the outpatient unit, and it causes another long waiting line at the blood collection counters.

In the present case study, the hospital is faced with outstanding limited resources (i.e., fewer blood collection counters) in the facility, which are shared among metabolism, nephrology, and other specialties. Long waiting queues occur apparently to receive blood tests. Besides, the time of blood draw is, on average, much shorter than the outpatient consultation time. After the patients get the blood draw, the report is generated in 40 minutes. Consequently, significant longer waiting occurs in the waiting area for outpatient appointments.

Blood collection is a serious issue that can affect the entire healthcare system.[10,11] It necessitates the use of the most effective and efficient approaches possible to address the issue at the hospital.[12] In this study, the goal is to investigate the resource allocation strategies regarding blood collection counters for improving patient waiting times in the outpatient units of both metabolism and nephrology divisions in the hospital. Specifically, we designed a discrete-event simulation (DES) model based on the existing patient flows and the collected operational data (e.g., patient waiting times), and patient census.

Literature Review

For centuries, patient waiting times (WT) have been a persistent issue in the healthcare industry.[13-18] Long patient WT can be caused by many factors and would affect the quality of care in hospitals.[19] Arneill and Devlin[17] concluded that the physical environment of the waiting room has an impact on the overall quality of care. Piette[20] found that shorter waiting times contributed to the satisfaction of patients with diabetes. In the healthcare system, WT can be measured through different stages, including patients waiting for appointments, diagnoses, elective procedures, and time spent in waiting rooms.[21] In general, it refers to the period when a patient enters a clinic until he/she sees the doctor.[16] When there is an imbalance between the number of patient visits and the available medical resources provided, an overcrowding problem appears.[22] The overcrowding problem has been one of the challenging issues for healthcare units, including outpatient,[23] inpatient,[24] and emergency departments.[25] When the problem occurs, it is

Table 1. Simulation Model Inputs With Real Data.

Model Inputs	Value in Minutes [Lower 95% CI, Mean, Upper 95% CI]
Blood draw patients arrival time (Departments of Metabolism and Nephrology)	(9.58, 10.9, 12.2)
Blood draw patients arrival time (other departments)	(2.82, 2.97, 3.12)
Model inputs	Value [lower 95% CI, mean, upper 95% CI]
Department of metabolism patients:1	1:(53.9%, 56%, 58.1%); 2:(41.9%, 44%, 46.1%)
Department of nephrology patients:2	
Patients consulting on the same day of blood draw (yes: 1, no: 2)	1:(80.4%, 82.6%, 84.7%); 2:(15.3%, 17.4%, 19.5%)
Number of patients in the Department of Metabolism without blood draw[a]	(1.48, 1.8, 2.13)
Number of patients in the departments of nephrology without blood draw[a]	(1.08,1.31, 1.54)
Model inputs	Distributional assumptions in minutes[b]
Blood draw processing time	Uniform (3, 5)

[a]Number of patients per hour.
[b]Distributional assumptions minutes are suggested by physicians and medical technologists.

leading to inefficient patient flows and a long patient WT. Moreover, the problem is associated with delayed treatment for patients, lower patient satisfaction, increased number of medical errors, and higher patient mortality.[26]

Numerous studies and hospitals have paid attention to overcoming the long WT problem. Wait and visit time estimation, bottleneck elimination, schedule optimization, and resource allocation are several common solutions to improve patient flows.[27] Discrete-event simulation is one of the popular analytical techniques to address the problem. DES is able to simulate dynamic events and interactions between processes and entities for competing resources in complex environments such as hospitals.[28] The mission of a DES model is to compare potential strategies that are usually difficult to implement one by one due to substantial costs and risks.[29]

Almomani and Alsarheed[30] identified five main problems that cause long patient WT in one of Saudi Arabia's hospitals. In their study, a simulation model was built to evaluate the effectiveness of potential solutions. The average WT can be reduced by 54.2%. Aeenparast et al[31] also proposed several strategies in a simulation environment to reduce outpatient WT. Zhu et al[32] analyzed the main factors that influence long patient WT in an outpatient clinic in Singapore. Four improvement settings using a simulation model are proposed and the average WT is improved by 52%. Komashie & Mousavi[33] applied DES in England hospitals and the improved flows reduced the WT up to 20%. Nguyen et al[23] evaluated WT in all outpatient processes at a national hospital in Vietnam using a computerized method of automated time recording. Hoot et al[34] introduced DES in real-time forecasting in ED. Ceyhan and Turkcan[35] used DES to compare several appointment scheduling and staffing methods for better patient flows and lower waiting times. In some studies, DES and other techniques were used together to simulate nurse mobility and establish relationships between various departments.[36,37]

To provide better medical care services, it always needs to ensure sufficient resource supplies such as spaces in hospitals (e.g., numbers of blood collection counters and diagnosis rooms) to meet patient needs. However, it is difficult for policymakers and providers to decide how to reduce WT for primary care appointments.[15] It shows that most of the literature only focuses on improving performance, such as length of stay in the emergency department[26,38-40] or outpatient appointment scheduling and resource allocation.[41-46] However, the importance of effective blood counter settings for better patient flows is not discussed. Furthermore, how different blood counter settings affect patient waiting time in the outpatient units of both metabolism and nephrology divisions is missing in the literature. To address the research gap, we are motivated to propose potential strategies to analyze the settings of blood collection counters using DES.

Methods

Model Development

According to the data analysis of outpatient flows, including registration time and consulting time, and the categories of patients, containing departments, the requirement for the blood draw, and consulting on the day or the other day, in Departments of Nephrology, Metabolism, and Laboratory at a regional hospital in Taiwan in Mary, 2019, a model is constructed (Table 1) to simulate the process of patients in other departments and Departments of Metabolism and Nephrology receiving blood draw in Department of Laboratory. In DES, the patient behavior of each operation process in the outpatient units is considered a discrete event. The first event is the registration process at the blood collection counters. After subsequent visit patients arrive at the hospital, they will register at the Department of Laboratory and stay in the waiting area on the first floor, with about 25 seats. They are queued to do the blood draw. The second event is the blood drawing process. After finishing the blood draw, these patients see the doctors in the Department of Metabolism or Department of Nephrology according to their preference and consulting day. First visit patients for the Department of Metabolism and Nephrology are not necessary to do a blood

Table 2. Average Consulting Time of Physicians in the Department of Nephrology and Metabolism at Different Periods in May (Unit: Minute).

Week	Time Period	Office Number	Mon	Tues	Wed	Thurs	Fri
1 (5/1)	Morning session	1					4.354
		2					
		3					
	Afternoon session	1					6.667
		2					
		3					
2 (5/4~5/8)	Morning session	1	4.56	5.666	3.866	4.756	4.822
		2	2.08	4.345	3.487	4.41	3.916
		3	5				
	Afternoon session	1		6.53	5.583	2.5	4.875
		2		4.225		4.425	
		3					
3 (5/11~5/15)	Morning session	1	6.32	3.586	4.296	4.13	4.75
		2	7	4.22	3.732	3.43	
		3	3.75				
	Afternoon session	1		5.466	5.277	3.666	6.625
		2		4.047		4.4358	
		3					
4 (5/18~5/22)	Morning session	1	5.24	6	3.870	4.703	4.263
		2	4.146	4.677	5.095	3.684	3.394
		3	5.214				
	Afternoon session	1		3.896	4.558	4	7.214
		2		4.133		4.685	
		3					
5 (5/25~5/29)	Morning session	1	4.354	5.333	4.029	5.444	5.533
		2	2.43	3.818	4.216	3.75	
		3	5				
	Afternoon session	1		5.857	6.15	3.25	6.818
		2		3.796		4.978	
		3					

draw; therefore, they should directly go to the department. The third event is the registration process at the departments. After registering at the Departments of Metabolism and Nephrology, they would stay in the waiting area on the third floor, where there are about 30 seats. If there is no vacancy, patients will have to stand and wait. The fourth event is the diagnosis process, where each patient is assigned to a doctor for a diagnosis. After that, the patients leave the hospital.

The shift schedule of physicians in the Departments of Metabolism and Nephrology is based on the Internet registration information, removing the time a physician takes up from other physicians' consulting time. Since the consulting time of physicians shows large changes, each physician's consulting speed at the period is divided in this study. Physicians' consulting speed might be affected by the number of patients; the consulting time would accelerate with more patients. Table 2 shows the average consulting time of physicians in the Departments of Nephrology and Metabolism at different periods, which is divided into morning sessions from 8 AM to 2 PM and afternoon sessions from 2 PM to 6 PM, without considering the change in patients' consulting time in the period.

There are seven blood collection counters in the Department of Laboratory. The shift schedule of the blood collection staff is judged according to the number of blood collection counters preceding blood draw and blood test at the time. The number of available blood collection counters ranged from four to seven stations. It would take about 40 minutes for detecting instruments outputting blood test reports after a blood draw.

The simulation model of patients from blood draw to outpatient is constructed with the discrete-event simulation tool, Simul8, to trace the indicators related to WT and the number of waiting patients, including the classification of the maximum and average waiting time for waiting for the test, blood draw, and blood test report before outpatient in Departments of Metabolism and Nephrology. The maximum number of waiting patients is divided into patients in the waiting areas on the first and third floor. With the above indicators, it attempts to understand whether the improvement strategies could reduce outpatient congestion.

Current Outpatient Condition

The peak number of patients waiting at the Departments of Metabolism and Nephrology in May is 41, concentrating on 8–10 AM, Monday. Because one more physician is served at

Table 3. Outpatient Stay Indicators Under Different Strategies.

Scenario	The Maximum Number of Patients Waiting	Maximum Waiting Time (min)	Average Waiting Time (min)	Improve Efficiency
Original	41	201.6	22.6	Baseline
S1	24	149.4	17.8	(41%, 26%, 21%)
S2	39	201.3	21.6	(5%, 0%, 4%)
S3	38	235.2	22.3	(7%, −17%, 1%)
S4	32	202.4	22.2	(22%, 0%, 2%)

Table 4. Outpatient Stay Indicators Before and After Strategy Implementation.

Scenario	The Maximum Number of Waiting Patients	Maximum Waiting Time (min)	Average Waiting Time (min)	Improve Efficiency
May (Original)	41	201.6	22.6	Baseline
July	33	83	21	(20%, 59%, 7%)

Table 5. Blood Collection Counter Stay Indicators Before and After the Strategy are Implemented.

Scenario	The Maximum Number of Waiting Patients	Maximum Waiting Time (min)	Average Waiting Time (min)	Improve Efficiency
May (Original)	31	120	25.1	Baseline
July	31	120	22.1	(0%, 0%, 12%)

the Department of Nephrology on Monday compared to other weekdays, more patients prefer to register on Monday. It is also observed that the maximum waiting time for patients to get the diagnosis at the Department of Metabolism is 202 minutes and the average waiting time is 22 minutes; the maximum waiting time for patients to get the diagnosis at the Department of Nephrology is 106 minutes and the average waiting time is 23 minutes; the maximum waiting time for patients to get the blood draw is 120 minutes and the average waiting time is 25 minutes; the maximum/average waiting time for outputting the blood draw report is 40 minutes.

Strategy Analysis

It is discovered in this study that the handling speed of blood collection counters higher than outpatient diagnosis speed is the major factor in outpatient congestion; besides, patients in the same department preceding blood draw through several blood collection counters would result in large crowds flooding the department. Four improvement strategies with exclusive blood collection counters were simulated and compared by the outpatient stay indicators (Table 3). Strategy 1 and 2 assign one and two exclusive blood collection counters all day to Departments of Metabolism and Nephrology patients. Strategy 3 and 4 assign two and one exclusive blood collection counters between 8 and 10 AM.

After discussing with hospital staff, Strategy 4 is suggested as the best one, because the resources used in blood collection counters are the least, with the least effect on blood collection

counters; the maximum number of patients waiting at the blood collection counter is only increased by 1 minute, but it presents the most significant improvement efficiency 22% on the maximum number of patients waiting in outpatient clinics. Strategy 4 was selected for the on-site test in July.

Results

We compared the number of blood draws in May and July. The number of blood draws for the Departments of Metabolism and Nephrology decreased by 57 in May, compared to in July, while blood draw patients in other departments decreased from 4444 to 3951. Consequently, in addition to presenting the test results in July, the real patient visit data in July were also input into the simulation model, and the number of patients in other departments in July was replaced with the number of patients in other departments in May in order to test the effect on departments. It has been discovered that the average waiting time in July, after the implementation of Strategy 4, is shorter than that in May. Besides, replacing the number of patients in other departments in July with those in May does not remarkably affect the average waiting time in July.

Tables 4 and 5 show the comparison of outpatient stay indicators before improvement in May and after improvement in July revision. It has been discovered that the implementation of Strategy 4 decreases the maximum number of patients waiting in the Department of Metabolism from 41 to 33 (20%), and the maximum waiting time in front of workstations decreases from 202 minutes to 83 minutes, with an improvement

rate of 59%. The main reason is that Strategy 4 would bring more patients queuing at the blood collection counters instead of waiting in front of the outpatient clinics. Besides, replacing patients in other departments in July with those in May does not notably affect the maximum waiting time in July. In this case, the difference in the number of patients in other departments in May and July would not remarkably affect the result of the implementation of the strategy.

The results showed that the maximum number of patients waiting on the third floor in May and July decreased from 41 to 33 per hour. It also displayed the maximum number of patients waiting for blood collection on the first floor in May and July increasing from 1 to 24 per hour to share the congestion on the third floor to the blood collection counter and allowing adequate seats for patients waiting at the outpatient units comfortably. The number of waiting patients in July revision and July is about the same that the number of patients in other departments would not affect the number of waiting patients.

Conclusions and Discussions

The research reveals that the outpatient stay indicators could be improved through the adjustment of cross-department patient handling speed. Although the shortening of maximum waiting time might result from the decreased number of patients waiting at the Departments of Metabolism and or other factors, it has been discovered that exclusive blood collection counters at a specific time could reduce the maximum number of patients waiting in outpatient units and accelerate the blood collection speed of patients in other departments, as patients in Departments of Metabolism and Nephrology do not occupy other blood collection counters.

Previous research usually considered the improvement process for a single unit of the hospital. For example, Algiriyage et al[47] proposed different scheduling rules at an outpatient department and WT could be decreased by 60%. Other studies applying different scheduling algorithms were also able to reduce WT significantly.[30-32] However, the results are not comparable. It is noted that the patient flows in this study are distributed to two outpatient units and the Department of Laboratory. An effective modification of the current setting to improve patient flows requires cross-departmental collaboration.[48] The results provided new insights to utilize patient flows and improve WT.

Theoretical Contributions

DES has been proven as an effective tool to simulate different strategies for reducing waiting time.[49] DES has been used in the healthcare industry for the past decades as the standard technique of analysis.[50] The goal was to shorten nurses' travel distances, as determined by the association of clinic divisions. A study conducted in northwestern Iran's medical universities demonstrated that by using certain models, the waiting time before administration to the examination room may be reduced.[51] To our knowledge, the number of studies on blood collection counter resource allocation was limited or even none. This study has two theoretical contributions. First, this study contributes to proposing a new outpatient stay indicator for the number of waiting patients and describes the complete waiting experience of patients in the hospital through the provision of seats. Second, previous DES literature on healthcare process improvement does not consider the blood collection process as a significant indicator for reducing WT in patient flows. Hospitals are complex system in which resources interact and compete with each other. This study is able to add value to the existing literature by providing blood collection counter setting allocation strategies using DES.

Practical Implications

Many previous researches have suggested three directions to reduce outpatient WT, including resource alignment, operational efficiency, and process improvement.[52] The medical resources in a hospital are constrained. Therefore, expanding the blood collection team or adding more blood collection counters would not be a feasible solution to the current operations. We argued that adding resources or changing the process might not be recommended by medical staff or hospital managers since the benefits do not increase significantly. This study proposed effective strategies that solve the outpatient clinic overcrowding problem. The strategies take the least operational impacts and fewer costs into consideration. Other healthcare organizations would also adopt the concepts and models for their improvement plans in the future. The simulation of the improvement strategy with the establishment of an exclusive blood collection counter could reduce outpatient waiting indicators and outpatient congestion. The results provide managerial insight regarding the cost-effective strategy selection for the hospital operational strategy.

Limitations

This study has limitations. In the field test process, such a measure is human intervention that patients would have responses to the experiment and consider the blood collection priority being interfered with. If patients' blood collection sequence is automatically arranged by the system and the intervention is preceded with ranking, it would reduce patients' doubt and have patients comfortably waiting for seats and present a more significant improvement with the strategy. Second, although the study aimed to improve WT, healthcare organizations with different characteristics would have different predictors.[53] The model and strategies have to be modified in order to fit other healthcare organizations.

Declaration of Conflicting Interests

ORCID iD

Shao-Jen Weng ⓘ https://orcid.org/0000-0003-2230-6775

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