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OPERATIONS ANALYSIS AND APPOINTMENT SCHEDULING FOR AN OUTPATIENT CHEMOTHERAPY DEPARTMENT

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ABSTRACT

With current increasing demands for outpatient medical services, healthcare providers have had to analyze methods for providing safety and quality care services under constrained resources. A long waiting-time has a severe impact not only on the patients' satisfaction but also on the physical conditions of the patients, who receive invasive treatment in ambulatory care facilities. Patients treated with outpatient chemotherapy have been rapidly increasing over the last decade in Japan. In this context, a discrete event simulation model for exploring appointment scheduling in an outpatient chemotherapy department of a general hospital was developed. An efficient schedule was identified that held bed utilization to a tolerance level by restraining the excess waiting-time in a clinical setting. It is suggested that a scheduling method based on the infusion time be available for the outpatient chemotherapy department.

1 INTRODUCTION

Outpatient chemotherapy is a new type of outpatient medical service. The number of patients having cancer treated in an outpatient chemotherapy department (OCD) has been rapidly increasing in Japan, after ambulatory treatment using anti-cancer infusion drugs was first given reimbursement approval under the national medical insurance in 2002. The development of new drugs that control side effects caused by anti-cancer drugs helps patients to receive chemotherapy in outpatient departments. Moreover, ambulatory treatment helps patients to maintain their daily lives as much as possible and to reduce the stress that occurs during admission. In addition to the merit for the patients, there is an advantage to the national insurance system with respect to reducing the medical cost, which is attributed to the admission fee. Hence, treatment in an OCD is promoted from the standpoint of both the patients and the service providers. Recently, many hospitals have had to extend their treatment capacity to accommodate increasing numbers of patients under the limited medical resources of Japan.

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With the increasing demand for treatment in OCD, patients' waiting-time tends to be prolonged. A long waiting-time decreases the patients' satisfaction and imposes a further burden on the patients in addition to having painful chemotherapy. Previous research studies have revealed that effective appointment scheduling (AS) can minimize both the patients' waiting-times and the doctors' idle times as a result of regulating the flow of patients through the outpatient department (Cayirli and Veral 2003). AS in outpatient medical services has been one of the important subjects in health care administration.

Within the appointment systems in outpatient departments, there are many types of systems that are modifications and/or combinations of two basic systems: one is the single-block appointment system and the other involves individual appointments. Wijewickrama and Takakuwa (2006) summarized major AS rules or systems for outpatient departments as follows: the single-block system, the individual-block/fixed-interval system, the individual-block/fixed-interval with an initial block system, the multiple-block/fixed-interval rule, the multiple-block/fixed-interval rule with an initial block rule, the variable-block/fixed-interval rule, the individual-block/variable interval rule and the variable-interval appointment-scheduling system. There are some modified rules (Wijewickrama and Takakuwa 2005, Wijewickrama and Takakuwa 2008).

There are different types of delivery systems in outpatient care services. Conventional outpatient departments in hospitals and primary care clinics are charged with general consultation and elementary treatment. New delivery systems called Ambulatory Service Centers (ASCs) (Bowers and Mould 2005) provide specific medical services exclusively, such as interventional procedures for pain management, day case surgery, endoscopic examination/treatment, radiation therapy or chemotherapy. The AS rules for traditional outpatient departments have been developed and modified, while AS for new types of delivery systems, including the OCDs, remain to be explored. Some studies for the ASCs examine the effect of the arrival time on performance (Dexter 1999; Huschka et al. 2007; Huschka et al. 2008; Pirolo et al. 2009; Ogulata et al. 2009; Centeno, Dod, and Aranda 2010; Sambeek et al. 2010).

Dexter (1999) indicated that long waiting-times for patients were related to having a long consultation time in the preanesthesia evaluation clinic. He suggested that the commonly applied AS in outpatient departments was insufficient for the anesthesia clinic, to reduce the patient waiting-times. Centeno et al. (2010) suggested considering the type of endoscopic procedure that was required, based on an analysis of the low throughput in an endoscopy center, which employed block scheduling. Huschka et al. (2007) applied *job hedging* to AS in an outpatient procedure center that consisted of a patient waiting area, pre/post procedure rooms and operation rooms and found that the expected overtime and the patient waiting-time were more influenced by the arrival time schedules rather than the surgery allocation and sequencing.

The arrival times in those studies were allocated based on several rules that are employed in a conventional outpatient department or operation room (OR). It is assumed that the appointment scheduling in ASCs ought to consider the characteristics of the medical procedures and the patients' flow in each type of unit. There are only a few studies that address AS in an outpatient chemotherapy department.

This study focuses on the appointment scheduling of patients treated in an OCD at a medium scale general hospital located in Kobe, Japan. The purpose of this study is to identify the best scheduling rules based on the characteristics of the medical process in OCDs using a discrete event simulation.

2 DESCRIPTION OF THE OUTPATIENT CHEMOTHERAPY DEPARTMENT

The outpatient chemotherapy department (OCD) is a clinical unit of Kohnan Hospital in Kobe, Japan. This hospital has a total of 400 beds in 9 wards for inpatients and a mixed-patient outpatient department that includes 17 specialties. The OCD supports over 100 patient treatment visits per week. Patients with various types of cancer, such as breast cancer, colorectal cancer, uterine cancer, and lung cancer, are treated in the OCD. Some patients take adjuvant chemotherapy before or after surgery; some take it for radical cure and others take it for symptom management or the prolongation of life. The OCD service is provided from 9:00 to 17:00 on weekdays. There are a total of 4 chairs and 6 beds located in two large contiguous areas of the facility. Three registered nurses associated with the department work at the facility.

All of the patients receive chemotherapy by appointment according to their therapeutic planning. The treatment process is shown in Figure 1. A patient goes to the outpatient department to take a blood specimen collection after a general reception. Then, he/she has a medical examination taken by his/her own primary doctor in the department. The primary doctor checks the appropriateness of a prior prescription based on the examination results. If the doctor approves the prescription, then the final order is given. Two pharmacists on duty who compound infusions in the dispensary section receive the order. The pharmacist examines the prescription and begins the mixing of the drugs, provided that no concerns arise. If the patient condition is presumed not to be equal to the planned treatment, his/her appointment is canceled.

After having the medical examination, the patient moves to the OCD facility and steps into the OCD reception area. While the nurses of the OCD set up the equipment and prepare the patients for the therapy, infusion drugs are carried from the dispensary section located on another floor to the OCD facility by a porter. A doctor on duty and one of the OCD nurses then start intravenous infusion, and they administer an anti-cancer drug after confirming a patient's details, the medicine type and the dosage. After the administration of the drugs, a nurse checks the patient. If any abnormalities exist, the doctor decides whether to continue the treatment. After the treatment, a nurse examines the patient and provides instructions for home care.

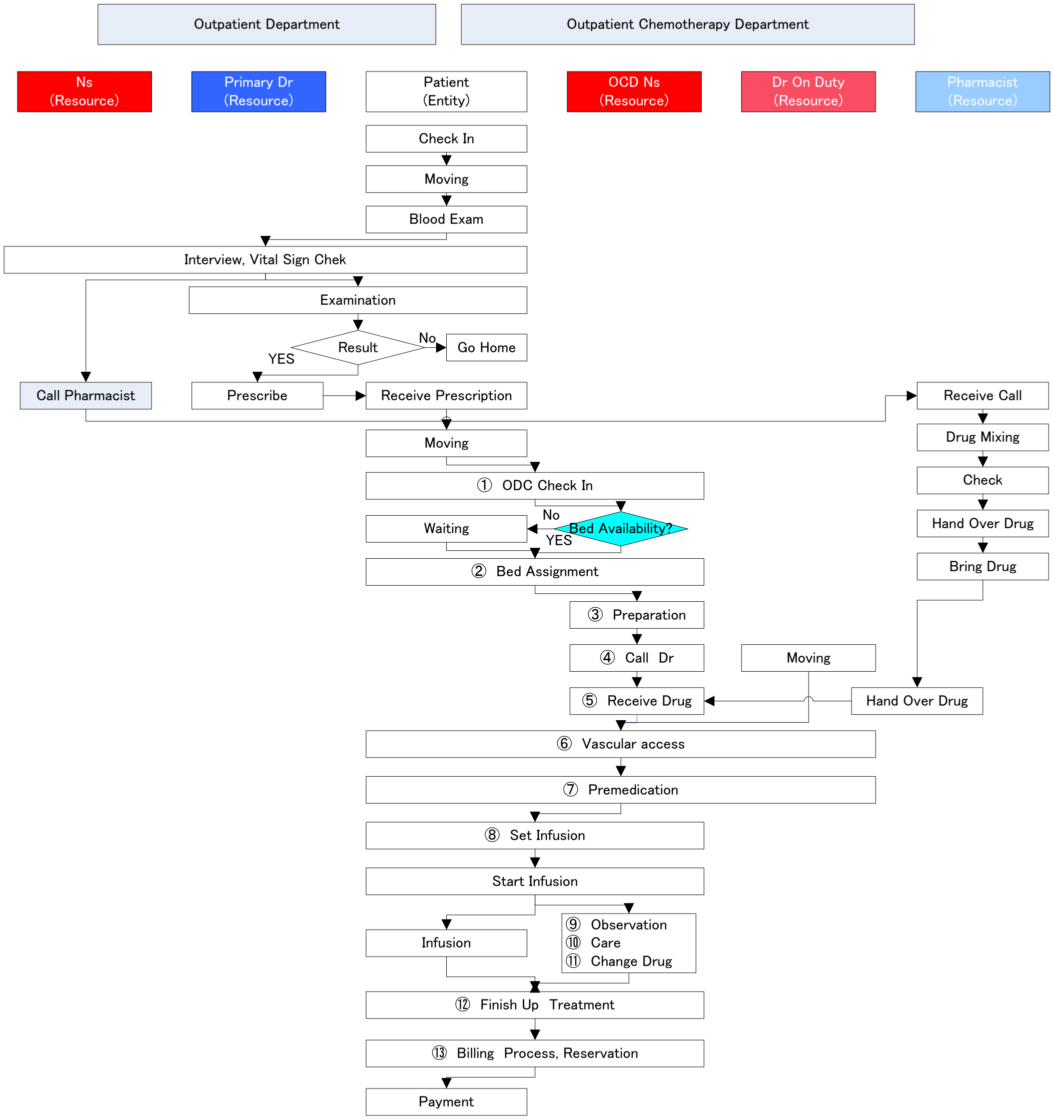

Figure 1: Medical process in the OCD

In general, a combination of medications and the administration time of the infusion are indicated in prescriptions according to a standardized protocol. For example, some patients with breast cancer are treated using regimen X, which includes a premedication such as a steroid by a bolus infusion for 1 minute, with the 1st infusion solution to reduce the side effects by infusion dripping intra-venous (DIV) for 30 minutes, a 2nd solution blended with anti-cancer drug A by DIV for 60 minutes, a 3rd solution blended with anti-cancer drug B by DIV for 60 minutes and the final solution to wash out drug toxicity by DIV for 30 minutes. The patients treated by this regimen spend minimally 181 minutes taking DIV in OCD beds. Other types of regimens (sets of drugs) for breast cancer patients require more long or short times to be completed according to the prescribed administration time. Moreover, patients with different types of cancer take specific regimens that are suitable for each type of cancer.

3 MODEL

3.1 Performance Measures and Data Collection

This study aims to identify the best scheduling rules based on the infusion time, which has an influence on the length of the OCD stay. A discrete event simulation technique is employed to find the optimal appointment schedule, which minimizes the patient waiting-time while maintaining the utilization of resources as high as possible under an actual therapeutic environment. Hence, three indicators are used to analyze the performance.

1. Patients' waiting-time in the medical process
2. Patients' total time in the medical process
3. Utilization of beds : the average percent occupancy of the total beds available

Data were collected via interviewing nursing administrators, reviewing medical records and conducting a time-motion study. The number of patients treated in a week, the diagnosis of each patient, the chemotherapy regimens (treatment plans that specify the dosage, the schedule and the duration of treatment) for each patient, the intravenous dripping time for each infusion solution that was blended with specific anti-cancer drugs, the percentage of cancelled treatments, and the staffing and sequence of the treatment process were collected. Continuous time-motion observations of medical activity were performed to record the actions, location, start time and completion time for each action. The subjects of the time-motion study were 3 OCD nurses, 2 pharmacists and a porter. The resultant data were used to extract the process time in the OCD treatment.

The patients were divided into 9 categories according to the type of cancer because the infusion time for each type of cancer patient was assumed to have a unique distribution. In general, some specific set of medications called *regimens* are prescribed based on the type of cancer being treated. As the beds in the OCD are taken, at least for the administration time of the infusion assigned by the prescription for each of the patients, the length of the OCD stay is assumed to depend primarily on the administration time of the drug infusion. The probability distributions of the infusion times were estimated by using the data of the medical record. The patient types, the percentage of each patient type and the delay time for the infusion DIV for each cancer type are summarized in Table 1.

Nursing activities were divided into direct services, in which the nurses provided care for the patients directly based on the medical process, and indirect services that were conducted as background jobs, e.g., recording, preparation for the treatment procedure, information exchange, or walking from one place to another. Using time-motion study data, probability distributions were estimated for both types of services. The indirect services can be detected with the frequency of occurrence for each time span (Table 2). The direct services, listed according to the medical process and the delay time for each step, are shown in Table 3.

Table 1: Patient Types and Parameters

Patient Type	Number per Day	Proportion %	Delay Time for DIV Infusion (Min.)
Gastric Cancer	1.26	6.3	TRIA(122, 206, 541)
Colorectal Cancer	3.50	17.5	TRIA(91, 185, 311)
Liver / Cholecyst Cancer	1.54	7.7	TRIA(108,174,212)
Pancreas Cancer	1.40	7.0	TRIA(32, 140, 242)
Kidney Cancer	0.28	1.4	TRIA(182, 187, 191)
Breast Cancer	7.27	36.4	TRIA(1, 93, 290)
Gynecologic Cancer	2.52	12.6	TRIA(122, 170, 322)
Lung Cancer	1.40	7.0	TRIA(122, 171, 212)
Other Cancer	0.84	4.2	TRIA(30, 140, 290)
Sum	20	100	

TRIA = Triangular

Table 2: Indirect Operation Process and Delay Time

Process Name	**Delay Time (Min.)**	**Frequency**									
		T8	**T9**	**T10**	**T11**	**T12**	**T13**	**T14**	**T15**	**T16**	**T17**
Record	TRIA (0.12,0.86,11.03)	0	1	5	3	5	2	6	4	2	3
Moving	TRIA (0.02,0.07,3.13)	15	62	50	46	36	38	52	63	22	35
Preparation	TRIA (0.02,0.62,20.47)	8	17	18	15	5	6	21	20	19	27
Information exchange	TRIA (0.05,0.36,4.9)	2	2	6	7	1	3	7	2	1	3
Information collection	TRIA (0.02,0.46,10.47)	3	11	1	11	9	8	6	6	4	7
Observation	TRIA (0.05,0.4,3.65)	2	11	5	7	5	3	6	7	4	2
Patient care	TRIA 0.18,0.27,2.43)	1	2	2	3	2	0	1	2	0	1
Toilets assistance	TRIA (0.13,0.269,1.52)	0	0	0	1	0	1	3	1	0	0

TRIA = Triangular, T8 = Time 8, ･･･T17 = Time 17

3.2 Simulation Model

A discrete event simulation model of the OCD was created using the simulation package Arena version 13.0 (Kelton, et al. 2010). In addition to the main patient flow, indirect nursing services were included in the model, such that the sequence of the medical process was substantially influenced by the nursing activity in the OCD. The estimated probability distributions were used in all of the processes of the patients flow and in indirect nursing services. Primary resources for the simulation were the 10 beds, with 1 doctor implementing vascular access and managing adverse events, 3 nurses in charge of the OCD, 2 pharmacists and 1 porter.

Table 3: Direct Operation Process and Delay time with Frequency

Section	Process Name	Delay Time (Min.)
Outpatient Department	Moving time to blood test room	1.5
	Blood exam	TRIA(2,4,7)
	Waiting for blood test result	TRIA(5,11,51)
	Moving time to chemo room	2
OCD	OCD receptionist	8+8.94*BETA(0.997,2.17)
	Bed assignment	LOGN(0.391,0.262)
	Receive drug	BETA(0.913,1.044)
	Call for OCD Dr	LOGN(0.317,0.38)
	Preperation for vascular access	TRIA(0.42,0.7,6.33)
	Vascular access	GAMM(1.32,1.13)
	Preparation for premedication	LOGN(1.29,2.09)
	Premedication	WIEB(1.32,1.2)
	Set infusion	LOGN(2.13,2.92)
	Finish up treatment	3.43*BETA(0.67,0.577)
	Billing process	0.03+1.97*BETA(0.79,0.736)
	Moving time to payment	3
	Payment	TRIA(5, 9, 15)
Pharmacy	Receiving call from outpatient department	0.06+0.23*BETA(0.614,0.66)
	Drug mixing	GAMM(0.816,1.29)
	Check drug	WEIB(0.216,1.07)
	Hand over drug to pharmacist assistant	0.04+0.11*BETA(0.991,0.939)
	Moving from Pharmacy to OCD	LOGN(0.169,0.141)
	Hand over drug to OCD Nurse	WEIB(0.559,1.61)

GAMM = Gamma, LOGN = Lognormal, TRIA = Triangular, WEIB = Weibull

The entities of the model were the patients categorized by the types of cancer. The model was a terminating simulation, in the sense that a finite number of patients were scheduled each day within a predetermined time in which the OCD was open.

In our preliminary experimentation, the patients were assigned to a probability of arrival and to the probability distributions for the infusion time according to the cancer type. The experiments were conducted to investigate the outline of the bed utilization in the OCD under the four conditions described below.

1. Increasing the number of nurses from 1 to 12 under patients’ arrivals were fixed at 40 (20 in the AM/ 20 in the PM)
2. Increasing the number of nurses from 3 to 7 when the patients’ arrivals were fixed at 20 (10 in the AM/ 10 in the PM)
3. Increasing the number of patients from 20 to 40 (half in the AM/ half in the PM) under an operation having 12 nurses.

4. Increasing the number of patients from 20 to 31 under an operation with 12 nurses.

The core simulation was conducted to define the optimal scheduling based on the infusion time on a typical day. In the model, the number of arrivals and the duration of infusion for 20 specific patients were fixed according to the data. The rules below were applied for patient allocations to the ten OCD beds in the model, as follows:

1. Listing the types of patients according to the duration of the infusion.
2. Sorting the list according to an ascending sequence of infusion times: {L(1), L(2), L(3),….L(n)}, where L(1) is the case in which the planned infusion time is the shortest and L(n) is the case with the longest planned infusion time.
3. Allocating patients arriving at the OCD for 10 beds as follows: { L(1), L(2), L(3),…L(10)}
4. Allocating subsequences as follows: {L(n), L(n-1), L(n-2),… }

With respect to the arrival time, we determined that the previous 10 patients arrived at the beginning of the day. The subsequent 10 arrivals occurred at times that were generated by subtracting the estimated mean time for pre-OCD procedures (including the general reception for checking in at the OCD) from the times at which the infusions for previous patients were completed (Table 4). The times to complete the infusions were determined based on the estimated distributions. This method was employed to identify the optimum subsequent arrivals, for both reducing the patients' waiting-time and increasing the bed utilization.

1. Using the probability distributions of the time to completion for the infusion, which was generated in the original model.
2. Varying the times of the secondary patients' arrivals according to the probability distributions for completing the infusion in the 5th to 95th percentile range

The design and analysis of the simulation model were adjusted and modified again by experts in industrial engineering, through many collaborative meetings. One hundred replications were simulated in all of the cases described above. The differences among the conditions were tested for statistical significance using a t-test, with $P < 0.05$ considered to be statistically significant.

Table 4: Distribution of the time to complete DIV infusion

Bed	**Distribution**	**Mean**	**±SD**	**Min**	**Max**	**5th percentile**	**50th percentile**	**95th percentile**
1	NORM(67.5, 19.1)	9:07:30	19.2	8:38:54	10:14:00	8:36:05	9:07:30	9:38:55
2	NORM(104, 20.1)	9:44:00	202.2	8:58:30	10:28:00	9:10:56	9:44:00	10:17:04
3	NORM(145, 16.6)	10:25:00	16.6	9:51:00	11:06:00	9:57:42	10:25:00	10:52:18
4	NORM(169, 15)	10:49:00	15.0	10:16:00	11:22:00	10:24:19	10:49:00	11:13:40
5	NORM(186, 15.9)	11:06:00	15.9	10:35:00	11:51:00	10:39:51	11:06:00	11:32:09
6	NORM(204, 18.2)	11:24:00	18.3	10:46:00	12:20:00	10:54:04	11:24:00	11:53:56
7	NORM(230, 23.9)	11:50:00	24.0	11:04:00	12:47:00	11:10:41	11:50:00	12:29:19
8	NORM(261, 25.1)	12:21:00	25.2	11:22:00	13:11:00	11:39:43	12:21:00	13:02:17
9	NORM(283, 22.2)	12:43:00	22.3	11:33:00	13:19:00	12:06:29	12:43:00	13:19:31
10	NORM(305, 17.1)	13:05:00	17.2	12:09:00	13:38:00	12:36:52	13:05:00	13:33:08

NORM = Normal

4 SIMULATION RESULTS

4.1 Evaluation of Bed Utilization in Preliminary Experimentation

Figure 2 shows the differences in bed utilizations that occur with increasing numbers of nurses, under the condition that the number of patients is fixed at 40. The utilization of the beds tended to increase under operations that involved 1 to 7 nurses. There was a significant difference only in bed utilization between the conditions of 1 nurse and 2 nurses (t=-3.448, p=.003). The results indicate that bed utilization showed a remarkable decrease in an operation having less than 2 nurses, who would be under the stress of attending to 40 patients. The bed utilization, however, showed no significant differences among the conditions of 3 to 7 nurses with an operation involving 20 patients (Figure 3). With respect to bed utilization, it would be adequate to operate with 3 nurses in the facility.

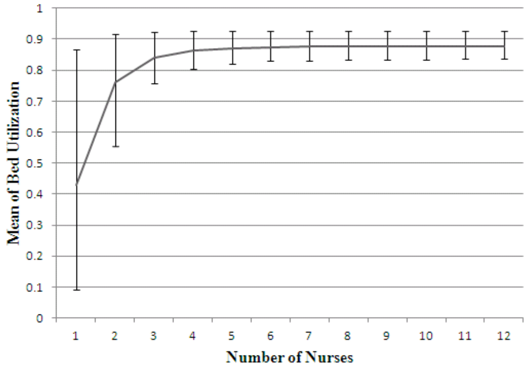

Figure 2: The impact of the number of nurses on the bed utilization when the number of patients is fixed at 40 (AM 20 / PM 20)

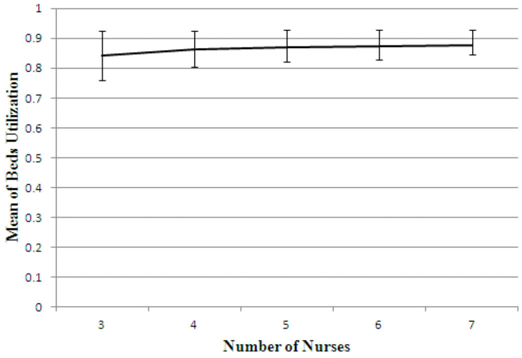

Figure 3: The impact of the number of nurses on the bed utilization when the number of patients is fixed at 20

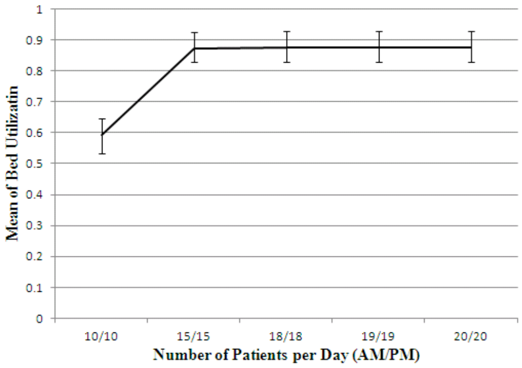

Figure 4: The impact of patient arrivals (AM/PM) on the bed utilization when the number of nurses is fixed at 12

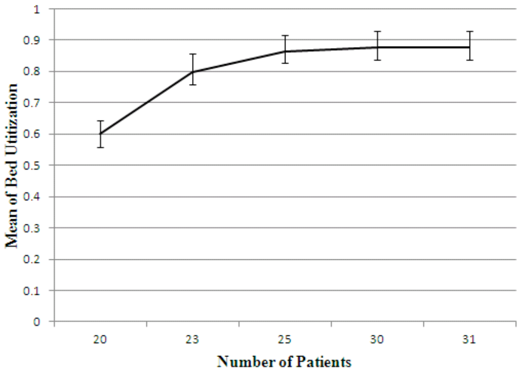

Figure 5: The impact of the number of patients on the bed Utilization when the number of nurses is fixed at 12

The impact of the number of patients on bed utilization is indicated in Figure 4. The condition in which 30 patients (15 in the AM/ 15 in the PM) were taken care of by 12 nurses showed a significant increase in bed utilization compared to a situation in which 20 patients were being cared for (t=-20.184, p<.000). Figure 5 shows the differences in bed utilization when there is an increasing number of patients (from 20 to 31) under an operation involving 12 nurses. There are significant differences in bed utilization under the condition of 20 patients compared to that of 23 patients (t=-14.972, p<.000) and 23 patients compared to 25 (t=-4.610, p<.000). The capacity of treatment would be assumed to be between 25 and 30 cases in this facility, even if the nursing resources in place were more than adequate.

4.2 Impact of ASs on the Service Time and Bed Utilization

The distribution of the time for 10 patients to complete their infusions is shown in Table 4, with estimated representative values. Figure 6 shows a gradual decrease in the measure of performance, the bed utilization, the waiting-time and the total time. The mean waiting-time of all 20 patients treated in a single day was 143.30 (min) for the 5th percentile of the distribution and 80.26 (min) for the 95th percentile. A waiting-time of over 2 hours in the treatment process would impose a severe strain on the patients from a clinical point of view. Although it is difficult to determine the latitude of the waiting-time in the treatment processes, it should be at least under 2 hours of wasted time. Setting the appointments for 2nd round patients at the time shown in the 40th percentile would be assuming to maintain the waiting-time at under 2 hours in this system. The mean utilization of 10 beds shows 0.67 under the condition of using the 5th percentile of the distribution and 0.57 when using the 95th percentile. If the appointment would be set above the 40th percentile of the distribution, then the utilization would decrease to under 0.6. The time of the 40th percentile of the distribution is limited to keeping the utilization above 0.6 in the OCD.

Figure 7 shows the changes in the proportions of the waiting-time out of the total time (WT/TT) and the means of utilization. In a clinical setting, WT/TT is expected to have an influence on the patient satisfaction, which would be similar to the influence of the waiting-time. The WT/TT was 0.40 at the 35th percentile and 0.34 at the 40th percentile, while it was 0.49 at the 5th percentile and 0.28 at the 95th percentile.

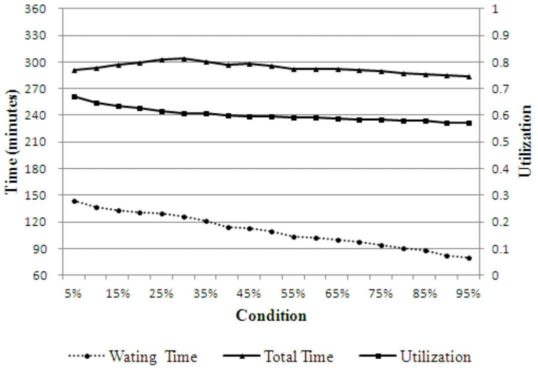

Figure 6: Service time and bed utilization

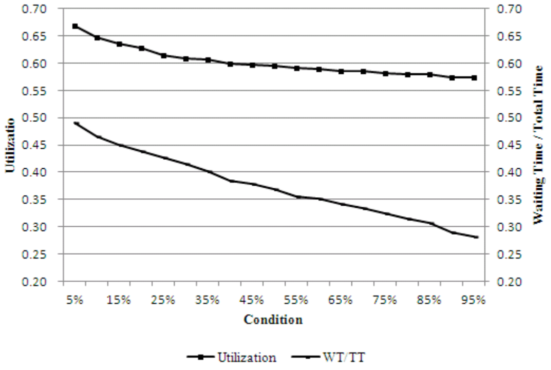

Figure 7: Bed utilization and WT/TT

The time for the 40th percentile of the distribution would be a convincing boundary to use for holding the WT/TT above 40%, with a tolerance for both the utilization and the waiting-time itself in this system. The last patient treated in the day checked out at 16:14, which was a moderate level among the conditions and allowed plenty of time for closing, with the condition of using the 40th percentile (Figure 8).

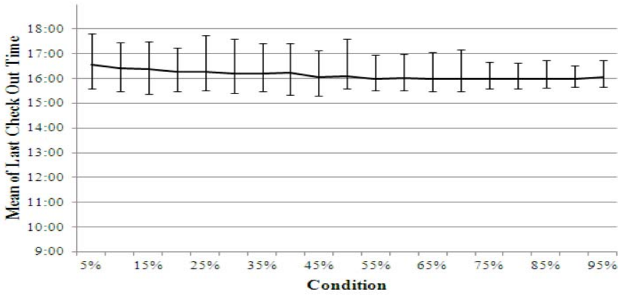

Figure 8: Check out time of last patient

Consequently, it is assumed that optimal appointments for 2nd round patients are scheduled based on the 40th percentile of the distribution of the time for previous patients to complete their infusions. This scheduling could maintain the utilization at 0.6 while restraining the waiting-time to under 2 hours and the WT/TT ratio to less than 0.4.

5 CONCLUSIONS

A simulation model of an outpatient chemotherapy department at a general hospital is constructed, to explore appointment scheduling based on the properties of the treatments. The results from preliminary experimentation show that the existing system has a treatment capacity of 30 patients under an operation involving 3 nurses with respect to bed utilization. The experimentation processes concentrated on the appointments for second treatment rounds over a single day and aimed to identify optimal scheduling, which shortens the mean of the waiting-time for all of the patients treated while maintaining the same bed utilization.

The results show that each performance measure has a tendency to decrease with later times of arrival, which are determined while accounting for the infusion time of previous patients. It was suggested that using the 40th percentile of the distribution for scheduling lowered the waiting-time while maintaining the bed utilization within a clinically permissible range during a typical day in the OCD.

Although the clinical relevance of the acceptable range for the waiting-times in an outpatient chemotherapy clinic requires more discussion, this scheduling rule can be made available for clinical management. First, this appointment scheduling rule could reflect the distinctions in outpatient chemotherapy for which patients receive infusions in bed during a designated period according to a prescribed regimen. Second, the rule is easily adapted to a clinical setting by using the pre-procedure time and the total infusion time of each type of cancer patient.

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