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Basic Original Report

Using a real-time location system to measure patient flow in a radiation oncology outpatient clinic

Kevin Conley MD [a], Chester Chambers PhD [b], Shereef Elnahal MD [a], Amanda Choflet DNP [a], Kayode Williams MD [c], Theodore DeWeese MD [a], Joseph Herman MD [a], Maqbool Dada PhD [b,*]

[a]*Johns Hopkins School of Medicine, Department of Radiation Oncology and Molecular Radiation Sciences, Baltimore, Maryland*
[b]*Johns Hopkins Carey Business School, Baltimore, Maryland*
[c]*Johns Hopkins School of Medicine, Department of Anesthesiology and Critical Care Medicine, Baltimore, Maryland*

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Abstract

Purpose: Common performance metrics for outpatient clinics define the time between patient arrival and entry into an examination room as "waiting time." Time spent in the room is considered processing time. This characterization systematically ignores time spent in the examination room waiting for service. If these definitions are used, performance will consistently understate total waiting times and overstate processing times. Correcting such errors will provide a better understanding of system behavior.

Methods and materials: In a radiation oncology service in an urban academic clinic, we collected data from a patient management system for 84 patients with 4 distinct types of visits: consultations, follow-ups, on-treatment visits, and nurse visits. Examination room entry and exit times were collected with a real-time location system for relevant care team members. Novel metrics of clinic performance were created, including the ratio of face time (ie, time during which the patient is with a practitioner) to total cycle time, which we label face-time efficiency. Attending physician interruptions occurred when the attending is called out of the room during a patient visit, and coordination-related delays are defined as waits for another team member.

Results: Face-time efficiency levels for consults, follow-ups, on-treatment visits, and nurse visits were 30.1%, 22.9%, 33.0%, and 25.6%, respectively. Attending physician interruptions averaged

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* Corresponding author. Johns Hopkins Carey Business School, Armstrong Institute for Patient Safety and Quality, 100 International Drive, Baltimore, MD 21202.

E-mail address: dada@jhu.edu (M. Dada).

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6.7 minutes per patient. If these interruptions were eliminated, face-time efficiencies would rise to 33.2%, 29.2%, 34.4%, and 25.6%, respectively. Eliminating all coordination-related delays would increase these values to 41.3%, 38.9%, 54.7%, and 38.7%, respectively.

Conclusions: A real-time location system can be used to augment a patient management system and automate data collection to provide improved descriptions of clinic performance.

Introduction

Clinical operations seek to minimize the natural tension that exists among the needs of patients, clinicians, and health care managers. From the patient's perspective, increased waiting time degrades the clinical experience, whereas increased time with the clinician ("face time") improves the experience.[1–3] From the clinician's perspective, delays add pressure to stay on schedule, and this time pressure decreases job satisfaction.[4] From a clinic manager's perspective, the inefficient use of costly labor leads to unplanned overtime and greater utilization of other capital resources, which ultimately leads to an increase in operating costs.[5] Thus, 3 principal agents in the system all benefit from reduced delays and increased efficiency.

Two key elements in virtually all prior studies on the efficiency of outpatients clinics are that the time between patient arrival and entry into an examination room is referred to as waiting time and that all time spent in an examination room is referred to as productive time. However, this characterization systematically ignores time that a patient spends waiting for service in the examination room. The purpose of this study is to demonstrate the use of novel technologies to help dissect patients' time in clinic and elucidate unproductive room time.

The setting for our efforts was a large-scale academic radiation oncology service. This clinic is particularly difficult to study for several reasons. Both patient mix and patient flow are relatively complex in these types of services.[6–8] This clinic accommodates at least 4 different types of visits with multiple attending physicians in parallel, in a shared space, and spread across multiple floors. Additionally, the clinic provides patient care and resident education simultaneously. Consequently, clinicians juggle competing demands during the course of a typical clinic session. For example, a clinician may have to interrupt a patient examination to go to another part of the clinic to approve the start of stereotactic radiation therapy for a different patient. Not surprisingly, the resulting interruptions contribute to delays while patients wait in examination rooms, and these delays ripple through the system to affect clinic operations.

To provide the detailed information needed for this analysis, we used a previously dormant real-time location system (RTLS) as a tool for data collection. We combined the RTLS data with information from a separate patient information system (Mosaiq) to create a more complete depiction of system behavior. We also provide an illustration of how such information can be used to predict improvements in performance metrics stemming from changes in behavior that can lead to lower waiting times, reduced operating costs, and increased efficiency.[6] In the process, we provide novel metrics of system performance and explain why common measurements of waiting times and processing times are inadequate and misleading. We hope that applications of our approach can be used to improve understanding of clinic operations.

Methods and materials

Our data were collected from an outpatient service within the Department of Radiation Oncology and Molecular Radiation Sciences at an urban academic clinic.[9] Within the clinic, we focused on the gastrointestinal service for detailed study because it had a physician champion and its operations were representative of other services within the department. The project was undertaken by a multidisciplinary project team consisting of clinicians and managers from the Department of Radiation Oncology and faculty from the business school. The care team in the gastrointestinal service consists of 1 attending physician, 1 resident physician, and 1 nurse in addition to a nurse practitioner who also provided other services independently.

We focused on patients scheduled to be seen in a defined area of 4 examination rooms. Over an 8-hour day, the appointment schedule included 15 to 20 patients. Appointment types included initial consultations; follow-ups; on-treatment visits for weekly symptom evaluation during the course of radiation therapy, and nursing visits, which address issues such as symptom management, review of information related to medications, and handling of consent forms. Follow-up visits consisted of either post-treatment follow-up visits or re-evaluations after a delay between the initial consultation and subsequent radiation treatment (eg, for systemic therapy). For consultations, follow-up visits, and on-treatment visits, patients were typically seen by a resident physician and/or a nurse prior to the attending physician.

Patient flow, MOSAIQ®, and real-time location system data

We collected de-identified data on all appointments for our clinical team during the period of March 14, 2016 to

April 30, 2016. These visits took place on 6 separate clinic days and totaled 84 appointments. In an idealized scenario, a patient with an appointment checked in upon arrival at time C. Then, the patient was seated in the waiting room until being escorted by a clinical assistant to one of four examination rooms at time IN. After being moved to the examination room, the patient interacted with care providers. We refer to the last time that a team member leaves the examination room as OUT and consider this the end of the clinic visit.

The clinic utilizes a patient management system, Mosaiq, which creates a new record when an appointment is made. Staff actions add to that record by recording a change in patient status. Status changes include arrival, recorded entry to an examination room, and closing the patient record. Mosaiq generates a daily report of all recorded changes in patient status. Ideally, recorded entry to the examination room is the same as time IN, and the record is closed at time OUT.

In reality, there is typically a lag between when the patient enters the room and when that time is recorded in Mosaiq. Similarly, there is also a lag between the time that the last provider leaves the room and this final status change is added to the system. These lags can be as short as 1 minute but can be considerably longer if staff are interrupted or called away to perform a different task before reaching the nurses' station or workroom. These lags make it impossible to accurately measure some aspects of system behavior, such as how long a patient waits in an examination room before facing a care provider. In addition, this record is not updated when a care provider enters or exits the examination room between the initial entry and final exit. Consequently, patient waits within the examination room are never recorded. Such measurements require the use of an additional data source.

This clinic housed an older RTLS that had been unused for several years but was still functional. This system included sensors in each examination room, the nurses' station, the work room, and several points in the connecting hallways. It was configured to provide a daily report, including time stamps for the movements of all team members. This feature allowed the team to correct estimated values for IN and OUT. Additionally, after merging these 2 data sources, we were able to co-locate providers and patients so that accurate measurements of waiting times within examination rooms and times spent with a clinician became available. Using these data allowed us to define a variety of performance measures (Table 1).

Cycle Time (CT) is defined as the last time stamp at which a provider leaves the examination room, or OUT, minus the earliest time that we know the patient is in the system, C. Initial Wait (W) is defined as the time the patient enters the examination room, or IN, minus the time at which the patient arrives, C. We can think of this as the traditional definition of waiting time. Room Time (RT) refers to the total time the patient spends in the examination room whether being treated or not and is calculated as OUT − IN. Consequently, CT = W + RT.

Because badges are assigned to each provider, we can find a service time for each resource for each patient. The total amount of time that a patient is in the same room as a team member is labeled Face Time (FT) and the total amount of time spent with the attending is labeled Attending Face Time (AFT). The time a patient spends in the examination room without the presence of a team member is labeled Room Delay, RD. Thus, RT = RD + FT. We also define Total Wait (TW) as all time during the cycle that the patient was not in the presence of a service provider. Thus, TW = W + RD.

We refer to the proportion of cycle time that a patient was in the presence of a care provider as Face Time Efficiency (FTE), which is calculated as FT/CT. We refer to the proportion of cycle time that a patient is in the presence of the attending physician as Attending FT Efficiency (AFTE), which is calculated as AFT/CT. These metrics are commonly used in many manufacturing and service delivery settings but are not known to have been used in outpatient clinics, perhaps because gathering the necessary data is costly without the use of a technological aid such as RTLS.

Table 1 Definitions of selected terms in order of appearance

Term	Definition
C	Check-in time; time patient checks in upon arrival
IN	Time stamp at which patient enters examination room
OUT	Time stamp at which last service provider exists examination room
CT	Cycle time; time between patient arrival and exit of last provider to leave examination room
W	Wait time; time between patient check in and patient entry into examination room
RT	Room time; time patient spends in examination room
FT	Face time; time patient shares examination room with care team member
AFT	Attending face time; time patient shares examination room with attending
RD	Room delay; time patient spends in examination room with no provider present
TW	Total wait; wait time plus room delay
FTE	Face time efficiency; face time divided by cycle time
AFTE	Attending face time efficiency; face time with attending divided by cycle time

Table 2 Selected metrics for visit and attending

Visit type	CT (min)	RT (min)	RD (min)	FT (min)	FTE (%)	AFT (min)	AFTE (%)
All types [a]							
Mean [b]	97.0	69.1	48.7	20.4	29.1	10.5	16.6
SD	71.6	60.1	57.3	18.0	20.5	9.4	17.4
CV	0.74	0.87	1.18	0.89	0.71	0.90	1.05
Consultation							
Mean [b]	129.4	98.4	60.2	38.2	30.1	18.1	13.6
SD	35.7	23.1	27.2	28.9	20.4	15.4	9.4
CV	0.28	0.23	0.45	0.76	0.68	0.85	0.69
Follow-up							
Mean [b]	129.1	90.3	67.8	22.5	22.9	11.3	12.7
SD	52.2	35.9	33.8	14.8	20.1	8.4	19.9
CV	0.40	0.40	0.50	0.66	0.88	0.74	1.56
Treatment-related							
Mean [b]	64.3	48.3	34.7	13.6	33.0	7.1	20.0
SD	79.4	73.4	73.0	10.8	20.7	5.5	17.9
CV	1.23	1.52	2.10	0.79	0.63	0.77	0.89
Nurse [c]							
Mean [b]	51.3	20.4	7.6	12.7	25.6	16.0	25.6
SD	NA	15.3	8.7	10.2	NA	4.1	NA
CV	NA	0.75	1.14	0.80	NA	0.26	NA

AFT, attending face time (time patient is in examination room with attending); AFTE, attending face time efficiency (AFT/CT); CT, cycle time (total time from arrival to exit); CV, coefficient of variation; FT, face time (total time patient is in examination room with at least one provider); FTE, face time efficiency (FT/CT); NA, not available; RD, room delay (time in examination room with no provider); RT, room time (time in examination room); SD, standard deviation

[a] All visits that yielded complete data

[b] Arithmetic mean over all observations

[c] Visit with a nurse or nurse practitioner

Results

Patient flow

We collected RTLS data for 84 patient visits. Mosaiq provided appointment times for these patients, and check-in times were retrieved for 71 of the 84 patients, facilitating the calculation of their initial waits. Table 2 shows that the average CT was 97.0 minutes per visit. Of this time, RT = 69.1 minutes. Thus, the average initial wait was 27.1 minutes. Considering the 4 visit type categories, average RT and CT were greatest for consults (98.4 and 129.4 minutes) and were less for follow-ups (90.3 and 129.1), on-treatment visits (48.3 and 64.3 minutes), and nurse visits (20.4 and 51.3 minutes).

Table 2 also describes waits within the examination room (RD). For consults, follow-ups, on-treatment visits, and nurse visits, RD averaged 60.2, 67.8, 34.7, and 7.6 minutes, respectively. Average RD across all visit types was 48.7 minutes. The FTE levels were 30.1%, 22.9%, 33.0%, and 25.6%, respectively, for the 4 visit types and averaged 29.1% across all types. When we focused more specifically on FT with the attending, we found AFTE levels of 13.6%, 12.7%, 20.0%, and 25.6%, respectively. Comparing RD with RT showed that 70.5% of patients' time in the examination room was spent waiting. Of the approximately 20 minutes of FT spent with providers on a typical visit, approximately 10 minutes was spent with the attending physician. The remaining 10 minutes were spent with the resident physician and/or nurse. Thus, of the approximately 97 minutes that a patient spent on an average visit, approximately 10 minutes (11% of the time) were spent with the attending physician, and 22% of the time was spent receiving direct service.

Real-time location system data, activity times, and interruptions

The ability to tag each team member is key because they do not move in unison. Consequently, values of IN and OUT are not sufficient to understand efficiency. For example, gaps in service were frequently caused by the attending physician being called into another room or part of the clinic for various reasons.

The RTLS provides detailed data that reveal when patients and care providers are co-located in examination rooms. This level of detail allowed us to measure and decompose the in-room waiting times for each patient. Considering the room delays shown in Table 3, each value consisted of three parts. We refer to the time between IN and the appearance of the next care provider to enter the room as "initial wait." Additionally, we can identify

Table 3 Selected metrics for visit and attending after removal of interruption times

Visit type	Interrupted time (min)	RT (min)	RD (min)	FT (min)	FTE (%)	AFT (min)	AFTE (%)
All types [a]							
Mean [b]	6.7	63.5	43.7	20.4	32.6	10.5	26.3
SD	14.9	58.7	57.9	18.0	23.3	9.4	22.9
CV	2.23	0.92	1.33	0.89	0.72	0.90	0.87
Consult							
Mean [b]	9.8	89.4	51.2	38.2	33.2	18.1	15.2
SD	12.7	17.5	31.9	28.9	23.5	15.4	11.7
CV	1.30	0.20	0.62	0.76	0.71	0.85	0.77
Follow-up							
Mean [b]	7.5	84.9	64.8	22.5	29.2	11.3	11.1
SD	12.7	34.8	33.9	14.8	24.4	8.4	9.0
CV	1.69	0.41	0.52	0.66	0.83	0.74	0.82
On-therapy							
Mean [b]	5.8	43.3	29.7	13.6	34.4	7.1	34.4
SD	17.4	72.7	73.0	10.8	23.7	5.5	23.7
CV	3.01	1.68	2.46	0.79	0.69	0.77	0.69
Nurse [c]							
Mean [b]	0.0	20.4	7.6	12.7	25.6	16.0	25.6
SD	0.0	15.3	8.7	10.2	NA	4.1	NA
CV	1.73	0.75	1.15	0.80	NA	0.26	NA

AFT, attending face time (time patient is in examination room with attending physician); AFTE, attending face time efficiency (AFT/CT); CT, cycle time (total time from arrival to exit); CV, coefficient of variation; FT, face time (total time patient is in examination room with at least one provider); FTE, face time efficiency (FT/CT); NA, not available; RD, room delay (time in examination room with no provider); RT, room time (time in examination room); SD, standard deviation

[a] All visits that yielded complete data

[b] Arithmetic mean over all observations

[c] Visit with a nurse or nurse practitioner

instances in which the attending spends time with a patient, then leaves the room, and later returns to continue interactions with the same patient. The time spans between the attending leaving and returning that are not filled by other care providers increase room delay and decrease efficiency. We chose to refer to these spans of time as “interruption time” because they are related to interruptions to the attending’s flow.

In some cases, patients spent additional time awaiting the arrival of a nurse and/or resident. These waits occurred prior to, in lieu of, or after the activities of the attending, depending on the nature of the visit. When we added these waits to the interruption times, we uncovered what we refer to as “inserted times.” Inserted times are caused by the fact that movements of care providers are not perfectly coordinated and may occur even when there is no interruption to the attending’s movements. Thus, for each patient, room delay is the initial wait plus any inserted time, and interruption time is a subset of inserted time.

To evaluate the impact of these factors on clinic flow, we considered what several process measurements would have been had these time spans been eliminated. Therefore, we dropped these times from the record for each patient in our data set and recomputed the performance metrics of interest to show the effect on system performance. Table 3 shows the values, which parallel those of Table 2, after we removed interruption times and assumed that all FT values remained the same. In this scenario, FTE levels increased to 33.2%, 29.2%, 34.4%, and 25.6% and AFTE levels rose to 15.2%, 11.1%, 34.4%, and 25.6% for consults, follow-ups, on-treatment visits, and nurse visits, respectively. When averaged across all visit types, FTE increased from 29.1% to 32.6% and AFTE increased from 16.6% to 26.3%.

Table 4 shows the parallel results when all inserted time was eliminated, again assuming that FT values remained the same. For this special case, FTE levels increased to 41.3%, 38.9%, 54.7%, and 38.7% and AFTE levels increased to 17.7%, 21.4%, 33.2%, and 38.7%, respectively. When averaged across all visit types, FTE increased from 29.1% to 46.9% and AFTE increased from 16.6% to 26.7%.

Discussion

Efforts to address multifaceted concerns about clinic operations depend on the availability of accurate information with regard to the duration of activities related to patient care. Historically, this information has been drawn from patient information systems, collected by clinic personnel, or reported by paid observers. In our experience, patient information systems provide insufficient data to fully describe the flows of care providers; having clinic personnel record their activity times interrupts process

Table 4 Selected metrics for visit and attending after removal of inserted times

Visit type	Inserted time (min)	RT (min)	RD (min)	FT (min)	FTE (%)	AFT (min)	AFTE (%)
All types [a]							
Mean [b]	30.3	39.1	18.8	20.4	46.9	10.2	26.7
SD	34.9	52.1	50.5	18.0	30.0	9.4	24.7
CV	1.15	1.33	2.69	0.89	0.64	0.92	0.92
Consult							
Mean [b]	33.1	65.3	27.1	38.2	41.3	18.1	17.7
SD	24.8	30.9	30.9	28.9	28.4	15.4	11.3
CV	0.75	0.47	1.14	0.76	0.69	0.85	0.64
Follow-up							
Mean [b]	38.6	51.7	29.2	22.5	38.9	10.9	21.4
SD	27.7	33.6	34.6	14.8	25.7	8.5	22.2
CV	0.72	0.65	1.18	0.66	0.66	0.78	1.04
On-therapy							
Mean [b]	25.2	23.8	10.1	13.6	54.7	7.1	33.2
SD	42.2	63.7	64.0	10.8	30.6	5.5	27.0
CV	1.67	2.68	6.32	0.79	0.56	0.77	0.81
Nurse [c]							
Mean [b]	7.6	12.7	0.0	12.7	38.7	10.7	38.7
SD	8.7	10.2	0.0	10.2	NA	9.7	NA
CV	1.14	0.80	11.73	0.80	NA	0.91	NA

AFT, attending face time (time patient is in examination room with attending physician); AFTE, attending face time efficiency (AFT/CT); CT, cycle time (total time from arrival to exit); CV, coefficient of variation; FT, face time (total time patient is in examination room with at least one provider); FTE, face time efficiency (FT/CT); NA, not available; RD, room delay (time in examination room with no provider); RT, room time (time in examination room); SD, standard deviation

[a] All visits that yielded complete data

[b] Arithmetic mean over all observations

[c] Visit with a nurse or nurse practitioner

flow and increases direct costs, and using paid observers raises additional issues of privacy and requires interpretations of patient and provider behavior that can be difficult for outsiders to make.

Fortunately, the increasing availability of RTLS has the potential to simplify and accelerate data collection without being intrusive, costly, or a threat to privacy. In theory, such systems can operate with a high level of precision, allow tracking of multiple resources as they travel within a facility, and automate data capture. In reality, successful implementations of these systems for quality improvement programs in outpatient clinics are quite rare.[10] Complicating issues include a lack of understanding of system capabilities, low levels of technological acceptance, and the sheer burden of the volume of data generated without clear utility.

In this study, we demonstrated that RTLS data can be integrated with data from patient management software to measure patient flows with the level of granularity needed for process improvement. These measurements are collected at virtually no variable expense, do not create any additional burden on clinic personnel, do not disrupt work flow, and preserve patient privacy. Such a system uses the interactions between patients and providers to give a comprehensive daily picture of clinic operations.

Our study highlights a critical issue in the analysis of patient flow. It is natural to assume that a patient is receiving service during the entire span of time in the examination room. Data drawn from patient management systems are sufficient to estimate efficiency under this assumption. Unfortunately, as we uncovered, this assumption can significantly underestimate the patient wait time and overestimate contact time with providers. The detailed mapping of provider movement on the basis of data from the RTLS revealed that the average RD within the examination room of 48.7 minutes exceeded the average 27.1 minute wait experienced in the waiting room. This finding is critical because RD relates to both room utilization and patient experience. Accounting for this delay makes the calculations of waiting time, FT, and resource utilization more complex but also more accurate.

Ideally, data from an RTLS can be used to identify all relevant activity times. However, study of the data collected revealed several complications. First, because the clinical assistant was shared across clinics, we were unable to guarantee 100% compliance for clinical assistants wearing the badge that related to the RTLS. These types of issues partially explain why using the RTLS as the only data source is not always feasible. By combining 2 disparate data sources, we were able to improve accuracy by spotting inconsistencies between the data files. This required a variety of steps to perform the needed data scrubbing, reconciliation, and interpretation. Additionally, combining data from 2 sources allowed us to define novel metrics of clinic operations such as FTE and attending AFTE. Actions that increased these measures improve value to the patient and can be considered when evaluating staffing and appointment policies in the future.

Several limitations of this study are apparent. First, we did not have tags on patients, which means that the data set remained incomplete. Room utilization is understated because the examination room remains occupied for some time after the last caregiver exits the room. Second, in several instances the time recorded for the patient's entry to the examination room should be adjusted to reflect time between being put in the room and having the CA record the event in the information system. Consequently, the in-room waiting times that we report are actually lower bounds on their true values. Our results may slightly understate these delays.

Third, our study dealt with one team over a short time span. Consequently, any interruptions caused by interactions between team members and those on other teams are not fully tracked. In addition, an expanded sample size would facilitate deeper analysis, including the incorporation of patient satisfaction levels. Hopefully, future studies can build on this study to address these issues.

Conclusions

We note the relationship between room delay and room utilization. Having an average room time of 69.1 minutes and an average room delay of 48.7 minutes for 84 patients means that 5804.4 minutes of room time was used to process these patients. If half of the room delays could be eliminated, it would take only 3759 minutes. Saving >2000 minutes of room time may allow the system to process the same number of patients using 3 examination rooms instead of four or may allow the system to accommodate greater patient volume.

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