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DATA ANALYSIS OF EMERGENCY DEPARTMENT LENGTH OF STAY FOR PATIENTS PRESENTING WITH HEADACHES

Eitan Giat	Sheba Medical Center, Ramat Gan, Israel	Eitan.Giat@sheba.health.gov.il
Michael Dreyfuss	Jerusalem College of Technology, Jerusalem, Israel	Dreyfuss@jct.ac.il
Yahel Giat*	Jerusalem College of Technology, Jerusalem, Israel	Yahel@jct.ac.il

* Corresponding author

ABSTRACT

Aim/Purpose	Patients' length of stay in emergency departments (ED) is a widespread problem that poses great hardship on patients and health providers alike. This paper's purpose is to reduce length of stay (LOS) for patients presenting to the ED with headaches.
Background	The increasing number of patients admitted to emergency departments challenges administrators to find ways to reduce the length of stay in the ED. The purpose of this paper is to quantify the potential reduction in LOS by modifying patient flow in the ED, for patients presenting with non-traumatic headache who require a non-contrast head computerized tomography (CT).
Methodology	A 41-month retrospective review was performed for all patients presenting to the Sheba ED with non-traumatic headache as the chief complaint and that were referred to CT during their visit. We distinguished between patients that had undergone the standard patient flow of first seeing a physician and only then referred to CT and patients that were sent to CT directly from the triage station, which is run by a triage nurse. For the former group, we identified their main patient flow epochs: arrival, triage nurse, physician referral to CT, performing CT, discharge.
Contribution	The contribution is two-fold. First, a practical recommendation for changes in patient workflow to reduce LOS. Second, it demonstrates how medical records can be used to analyze "what-if" scenarios on patient flow.

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Findings	During the period under review, there were 5501 headache patients out of a total of 196681 walk-in ED visits, a ratio of 2.79% (95% confidence interval [95% CI]: 2.72%-2.86%). Of the headache patients, 2961 patients were referred to CT and their LOS was 394 minutes (95% CI: 387-401). Modifying the standard patient flow so that patients are sent from triage immediately to CT will potentially reduce 121 minutes (95% CI: 118-124) from their LOS. These potential savings are concentrated mainly in the p.m. hours.
Recommendations for Practitioners	The potential LOS reduction can be achieved by modifying current patient flow for patients presenting to the ED with non-traumatic headache. Modifications should focus on late afternoon and evening hours. Accordingly, different proposals addressing the nature of these proposals are discussed.
Recommendations for Researchers	There is a plethora of information available in electronic medical records, which is yet to be harnessed to improve the management of health systems. Researchers could apply techniques used in this paper to benefit the health systems.
Impact on Society	Reducing LOS will positively affect not only patients who will receive faster service, but also health provider that are currently are operating in a crowded and stressful environment.
Future Research	The research can be expanded to other common patient main complaints such as abdominal pain or orthopedic injuries.

Keywords	electronic medical records, emergency department, length of stay, patient flow

INTRODUCTION

Overcrowding in the emergency department (ED) is a pressing healthcare issue globally (Morley et al., 2018) and it has been shown to negatively affect the quality of treatment, clinical outcomes and patient satisfaction (Bernstein et al., 2009; Morley et al., 2018; Richardson, 2006). Length of stay (LOS) is a common indicator for overcrowding (Hwang et al., 2011; Miake-Lye et al., 2018) and therefore developing and implementing methods to reduce LOS are expected to improve patient care and satisfaction.

In recent years, an increasing number of studies have suggested implementing changes in the ED to increase efficiency and thereby reduce LOS. Examples for these efforts include physician triage (Partovi et al., 2001), expanding the nursing scope of practice, and patient-flow design (e.g., creating fast track units) in the ED (Miake-Lye et al., 2018). Importantly, not all intuitive changes in the ED result in the reduction of LOS (Han et al., 2007). Therefore, implementing changes in the ED must be done with caution and preceded with a cost-benefit analysis of the effects of the intervention using available retrospective data (Miake-Lye et al., 2018).

This study was conducted in the ED of Sheba Medical Center (SMC), a tertiary state-owned hospital in Israel holding 1430 beds. Each resident in Israel is entitle to free public healthcare managed by one of the four HMOs operating in Israel. This system is funded by a progressive 3.1%-5% tax on income. We focused on patients presenting with non-traumatic headaches as their chief complaint. Non-traumatic headache is a common chief complaint in patients presenting to the ED, comprising 2-3% of all ED presentations (Chu et al., 2017; Doretti et al., 2019; Leicht, 1980; Munoz-Ceron et al., 2019; Torelli et al., 2010). A considerable portion of these patients undergo neuroimaging in the ED, mainly non-contrast head computerized tomography (CT) (Rizk et al., 2013). The cost of each CT is approximately 1000 NIS (approx. 280 USD), which the patient's HMO pays the hospital.

In SMC ED, patients are admitted by a triage nurse that subsequently refers them to an ED physician. Barring few exceptions, CTs are performed after an evaluation by an ED physician or an internist. After the CT is interpreted by a radiologist, the patient is seen again by a physician for a decision (admission, discharge, or referral to a physician from another discipline, usually a neurologist). As a result, waiting time in the ED for patients presenting with a headache will typically include waiting to see an attending physician, waiting to undergo the CT, waiting for the radiologist's interpretation, and waiting for a concluding second (or more) patient-physician meeting.

In the realm of medical care, the documentation of patient information is a critical component of the healthcare system (Meinert, 2005). Medical records provide a comprehensive history of a patient's medical conditions, diagnoses, treatments, and outcomes. The review of medical records is a fundamental aspect of medical practice, and it enables healthcare providers to make informed decisions regarding patient care. A thorough review of medical records allows clinicians to identify trends, establish diagnoses, monitor treatment efficacy, and facilitate communication between healthcare providers (Armstrong et al., 2019).

A well-organized medical record can provide valuable insight into a patient's health history, treatment plan, and outcomes. The accuracy and completeness of medical records are essential for quality healthcare delivery, as they ensure that healthcare providers have access to up-to-date patient information. Furthermore, medical record reviews can help healthcare providers identify areas for improvement in patient care, identify potential medical errors, and evaluate the effectiveness of current treatment plans. In summary, the review of medical records is a crucial element of healthcare delivery that enables clinicians to provide the highest quality care to their patients. (Karahanna et al., 2019).

Several studies have explored the use of medical records to improve emergency room waiting times. For instance, a study by Furukawa (2011) found that ED's with a fully functional electronic medical records system were associated with 22.4% shorter LOS and 13.1% shorter time to diagnosis or treatment. Similarly, a study by Ashfaq et al. (2019) found that the use of deep learning algorithms on electronic health records was able to predict patient readmission to ED's. Emergency departments can then optimize resources by focusing on these high-risk patients. In addition, a study by Sterling et al. (2019) found that the use of natural language processing techniques on triage notes from electronic medical records was able to identify patients' disposition. These studies demonstrate the potential for medical records, particularly electronic health records, to be leveraged using information science techniques to improve emergency room waiting times.

The information gleaned from the data allows us to propose a modification that helps eliminate the waiting time for the CT and its interpretation. Specifically, we suggest patient-flow modifications that enable the triage nurse or a designated physician to order the CT scan during the preliminary admission. Consequently, the CT scan and its interpretation will be available during the first physician's evaluation, which will result in earlier diagnosis and reduction of the patient's overall ED waiting time. In this study, we estimate the potential reduction in waiting times if this proposal is adopted.

METHODS

STUDY DESIGN AND SETTING

This study was a 41-month retrospective medical record review of patients admitted to the adult primary SMC ED. The data here did not include other EDs located elsewhere in SMC, (e.g., pediatric ED, gynecology ED, ophthalmology ED and psychiatric ED).

All admissions files in SMC ED are recorded in a computerized system except for power outage or server maintenance. In the study period there were only three instances of system disconnection of more than one hour. The duration of these disconnections was less than 2 hours each and therefore has a negligible effect on the data. The time and date of every change in the electronic files are also

recorded in the system. This enabled us to track the waiting times as well as the full content of the admission file.

During most hours (09:00-23:00), patients arriving to the ED in SMC are admitted either as bed-assigned patients, or walk-in patients. Walk-in patients arrive on their own, able to wait in the waiting room and move between the medical personnel unassisted. Bed-assigned patients usually arrive by ambulance and are transferred by stretchers. The latter group, which is significantly smaller than the former, is attended by medical personnel upon arrival and therefore does not represent the typical patient who experiences longer ED waiting time. We excluded the bed-assigned patients (185,047 patients) from our study as these patients are treated differently (and usually more efficiently) and do not go through a triage nurse.

DATA SAMPLE

Our sample comprises all the walk-in patients that visited the ED between August 1st, 2014 and December 31st 2017. The reason for August 1st was to allow the system to be in steady state after being integrated into operations during the end of 2013. The data cleansing included removing all the records without a discharge date (489 records), with a negative LOS (3 records) and with a LOS greater than 1440 minutes (101 records).

A negative LOS happens when the discharge time is earlier than the arrival time and could happen by incorrect time stamping. We also removed 608 records in which the patient's first recorded meeting with a doctor is later than the discharge date as this, too indicates incorrect time stamping. The reason for purging stays longer than 1440 minutes is that there were no visits with a LOS in the range of 1440 to 1800 minutes. Presumably, a LOS greater than 1800 minutes does not reflect the visit's actual duration. This final sample is denoted henceforward as *All Patients* and it comprises 196,681 unique ED visits with complete patient data.

Walk-in patients arriving to the SMC ED are received by a triage nurse that records their complaints. This record includes a code word of the chief complaint (e.g., headaches, abdominal pain, etc.) and a short description of the patient's complaints.

The sample *Headache Patients* comprises patients from *All Patients* for which the triage nurse recorded "headaches" as their chief complaint. Trauma related headaches are recorded as "trauma" in the chief complaint and are not included in the sample. Furthermore, *Headache Patients* does not include patients presenting with headaches as a non-chief complaint. *Headache Patients* comprises 5501 unique ED visits.

Non-Headache Patients comprises all the patients in *All Patients* that are not in *Headache Patients*. It comprises 191,180 unique ED visits.

CT Patients comprises patients from *Headache Patients* that received a non-contrast head CT during their ED visit. *CT Patients* comprises 2961 unique ED visits. Contrast CT was excluded from this group because this is a procedure with very specific and narrow indications whose preparation takes many hours. Thus, for the purpose of this study contrast CT is inherently different than non-contrast CT.

Non-CT Patients comprises patients from *Headache Patients* that are not in *CT Patients*, i.e., they did not receive a non-contrast head CT. *Non-CT Patients* comprises 2551 unique ED visits.

To determine how the CT affects the LOS we distinguished between patients who were sent to do a CT upon arrival and patients who followed the regular visit flow of first seeing a physician and then undergoing a CT. We first cleansed the data by removing the patients' whose CT interpretation time was after their ED discharge time (126 patients) or not reported (28 patients). The remaining (2933) patients in *CT Patients* were grouped into two complementing groups:

CT Patients-B (Before) are the patients that were sent to do CT before seeing a physician. Of note, a nurse cannot order a CT scan, so these patients were presented briefly (physically or verbally) to an attending physician before ordering the CT. *CT Patients-B* comprises 256 ED visits.

CT Patients-A (After) are the patients that were sent to do CT after seeing a physician. We removed from this group, 126 patients with multiple CT's that prevented us from correctly relating the times. After data cleansing *CT Patients-A* comprises 2551 ED visits.

VARIABLES AND DATA ANALYSIS

For each patient in *All Patients* we recorded the following time events from the patient's medical record.

- Arrival: The time the patient has been admitted by the ED admission clerk.
- First physician meeting: The first time the patient was seen by (any) physician (determined by the first electronic documentation made by the physician). Patients belonging to *CT Patients-B* have no record stating they saw a physician before undergoing CT and therefore their first physician meeting is after the CT.
- ED discharge: The time the ED admission clerk has discharged the patient.

The length of stay (LOS) is defined as the time between ED discharge time and arrival time.

The time to see a physician (TSP) is the period of time the patient waited until the first time they were seen by a physician. It is the time difference between arrival and the first patient-physician meeting.

We reported the mean, median and standard deviation (SD) of LOS and TSP for all the patient samples. For the larger samples (*All patients* and *Non-Headache Patients*), we also reported the first and ninth decile points but did not report the 95% confidence interval (95% CI) since it is very narrow. For the other patient groups, we reported the 95% CI of LOS and TSP.

For the *CT Patients*, the patient-flow times that we considered also include the times that relate to the CT. The timeline for these patients depends on whether they belong to *CT Patients-A* or *CT Patients-B*. For *CT Patients-A*, the patient-flow time events are Arrival (T1), triage nurse (T2), first physician meeting (T3), last physician meeting before CT (T4), CT beginning (T5), CT interpretation (T6), physician decision (T7) and ED discharge (T8). The relationships between these events are given by:

$$T1 < T2 < T3 \leq T4 < T5 < T6 < T7 < T8$$

With *CT Patients-B*, the patient-flow timeline connects the time event T2 directly with T5. The patient-flow of both patient groups is depicted in Figure 1.

To address the question of reducing LOS for *CT Patients*, we examined how much time would be saved if a "probable candidate" for CT were sent upon arrival to CT (see below how such candidacy can be determined). The patient can be either referred by the triage nurse or by a physician when they evaluate the patient. We reasonably assumed that the physician that orders the CT is the last physician before the CT, since it is typically the case that once patients are sent to CT, they go and wait by the CT waiting rooms and are not seen by any other physician in the meantime. Therefore, the time difference between having a physician ordering the CT to the triage nurse ordering the CT is the time difference between these two events, which is T4 - T2. We calculated means, standard deviations and the first and ninth decile value of these times.

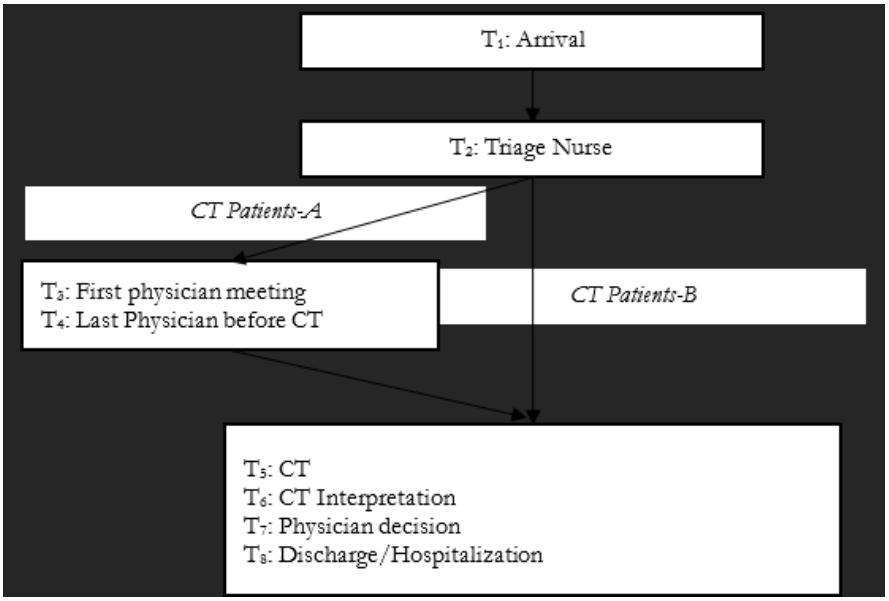

Figure 1: Patient-flow of CT Patients-A and CT Patients-B patients
Notes: CT = computerized tomography

An early (and simple) detection of candidates for CT is necessary to reduce LOS of headache patients. We therefore examined whether it is possible to identify the indicators that were most responsible for referring *CT Patients* to perform a CT. To this end, we evaluated 536 randomly chosen records from that sample. One of the authors (E.G.) reviewed these records and searched for any indication that justified a non-contrast CT scan according to the American College of Rheumatology appropriateness criteria for headache (Whitehead et al., 2019). Cases in which a reason or indication was not described by the referring physician, but the historical background or anamnestic details suggested a justified indication were also considered as a justified indication. Examples for justified indications are thunderclap headache, suspected meningitis or encephalitis, focal neurologic deficit or visual disturbances, new or progressive headaches in patients aged 50 years and older, and new headache in immunosuppressed patients or cancer patients. Cases in which no anamnestic detail or explanation by the referring physician suggested a need for CT were considered as "no indication".

RESULTS

The mean LOS of *All Patients* is 258 minutes with a standard deviation (SD) of 173 minutes. The median is 219 minutes, and the first decile and ninth decile points are 85 and 475 minutes, respectively.

Patient arrival rate varies during the day. Between 23:00 PM and 8:00 AM only 2.8% of *All Patients* arrived and therefore these hours are of little practical consequence. In Figure 2 we depict LOS and TSP for *All Patients* and *Headache Patients* according to their hour of arrival to the ED. By Figure 2 we observe that LOS increases until the early afternoon after which it is decreasing. It peaks between 14:00 and 15:00, and during that hour the expected LOS for *All Patients* is 285 minutes.

The LOS of *Headache Patients* is 351 minutes with a standard deviation of 192 min. The median, first and ninth deciles are 311, 152 and 599 min, respectively. *Non-Headache Patient*'s LOS is 256 minutes (SD =171, median first and ninth deciles are 217, 84 and 470 minutes, respectively). The LOS of *Headache Patients* is therefore 95 minutes higher than *Non-Headache Patients* (95% CI: 90-99).

TSP does not vary much across the groups. For *All Patients*, mean TSP is 114 (SD=72, median, first and ninth decile are 98, 40 and 210, respectively). For *Headache Patients* and *Non-Headache Patients* the mean times to see a physician are 123 and 116, respectively (for *Headache Patients*, SD, median, first

and ninth decile are 75,106,48 and 210, respectively, and for *Non-Headache Patients* 72, 98, 40 and 210, respectively). The difference between the means is only 8 minutes (95%: CI 6-10). One would not expect the difference to be large since the waiting times to see a physician are not supposed to depend on the type of complaint (except for triage considerations, which are far and few since our sample set is the walking patients).

Since TSP varies little between the groups, the large mean LOS difference between *Headache Patients* and *Non-Headache Patients* is mainly the result of the medical treatment that they receive after seeing an ED physician. To examine whether this can be attributed to the CT and whether some of this waiting time can be saved, we compared *CT Patients* and *Non-CT Patients*.

For *CT Patients* the mean LOS is 394 (SD, median, first and ninth decile are 189, 357, 192 and 642, respectively). For this group, the mean TSP is 123 (SD, median, first and ninth decile are 74, 107, 49 and 218, respectively). For *Non-CT Patients* mean LOS is 300 (SD, median, first and ninth decile are 183, 254, 121 and 537, respectively), and mean TSP is 121 (SD, median, first and ninth decile are 75, 105, 47 and 215, respectively). Thus, while the difference in TSP between *CT Patients* and *Non-CT Patients* is not significant and amounts to only 2 minutes (95% CI: -2-6), the difference in the mean LOS is significant and equals 94 minutes (95% CI: 84, 104).

In Table 1 we summarized the LOS and TSP statistical data of the patient groups. For each variable we presented the mean, standard deviation, median and first and ninth decile point values.

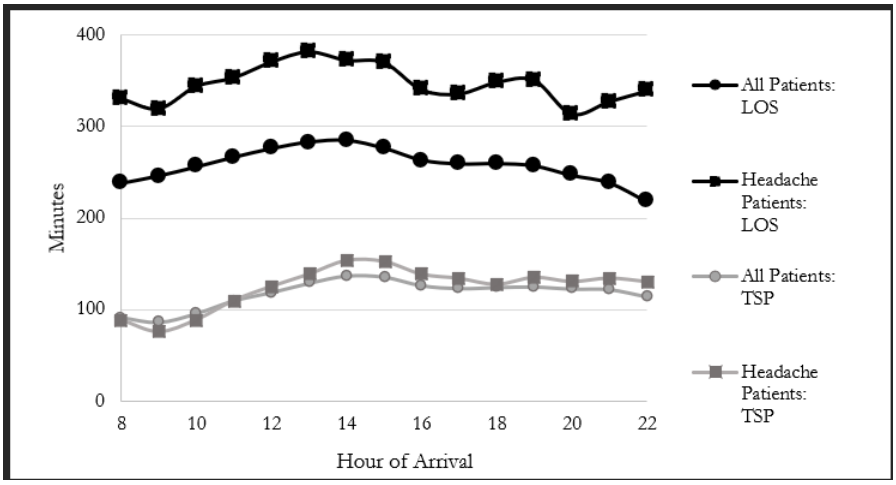

Figure 2: Patient-flow of *CT Patients-A* and *CT Patients-B* patients
Notes: LOS = length of stay; TSP = time to see a physician

Table 1: LOS and TSP statistics for the patient groups

Patient Sample	Sample Size	LOS – Mean (SD, Median, 10%, 90%)	TSP – Mean (SD, Median, 10%, 90%)
All Patients	196681	258 (173, 219, 85, 475)	114 (72, 98, 40, 210)
Non-Headache Patients	191180	256 (171, 217, 84, 470)	114 (72, 98, 40, 210)
Headache Patients	5501	351 (192, 311, 152, 599)	122 (75, 106, 48, 217)
CT Patients	2961	394 (189, 357, 192, 642)	123 (74, 107, 49, 218)
Non-CT Patients	2540	300 (183, 254, 121, 537)	121 (75, 105, 47, 215)
CT Patients-A	2551	396 (186, 361, 196, 643)	
CT Patients-B	256	370 (217, 311, 161, 634)	
Notes: LOS = length of stay; TSP = time to see a physician			

Next, we examined how performing a CT in the ED affects the patients' LOS. For the 2551 visits in *CT Patients-A*, the mean value of T4 - T2 is 121 minutes (SD, median, first and ninth decile are 85, 97, 40 and 233, respectively. 95% CI: 118-124). In other words, if these patients were sent to CT during the triage phase their LOS could potentially decrease by 121 minutes, on average.

In fact, the data suggests that ED doctors have been doing this unofficially, albeit on a very small scale. *CT Patients-B* is patients that were sent to CT before seeing a physician. Perhaps in these few cases the triage nurse proactively decided to call a physician and suggested ordering a CT for the patient. Table 1 also details the LOS statistics for *CT Patients*, *CT Patients-A* and *CT Patients-B*. For *CT Patients-A*, mean LOS is 397 (SD, median, first and ninth decile are 186, 361, 196 and 643, respectively), and for *CT Patients-B*, mean LOS is 370 (SD, median, first and ninth decile are 217, 311, 161 and 634, respectively). Indeed, the mean LOS of those ($256/2961 \approx 8\%$) patients who were immediately sent to CT is 27 minutes shorter (95% CI: 3-51). While this is a far cry from exploiting the entire 121 minutes of potential savings, this result indeed suggests that a change in the order of the CT and physician meeting is a beneficial move.

To see whether the initial complaint allows healthcare providers to easily predict which patients presenting with headaches will eventually undergo a CT, we examined a random sample of 536 patients from *CT Patients*. Of these, a clear indication for performing the CT scan was absent from the files in 321 patients (60%, 95% CI: 56-64%). In these cases, the indication resulted from the physician's subjective evaluation. In the remaining 215 cases (40%, 95% CI: 36-44%), a clear indication for performing a CT was described, such as a high suspicion of intracranial hemorrhage (as in patients with anticoagulation therapy, severe clapping headache, a significant head trauma in the past few weeks, brain metastases, or arterio-ventricular malformation), a high suspicion of an infection, or space occupying lesion involving the brain. In Table 2 we describe the medical conditions of the patients that compose these 215 cases. Of these 215 patients, 32 belonged to *CT Patients-B* (15%, 95% CI: 10-20%) and 183 patients belonged to *CT Patients-A* (85%, 95% CI: 80-90%). The mean T4 - T2 of the latter groups was 115 minutes.

Table 2: Medical conditions that prompted a CT scan before a full evaluation by an ED physician

Complaint	Instances	Percent
Clear neurologic complaints or abnormal neurological examination	73	34.0%
Head trauma within past weeks with progressive headache*	39	18.1%
Visual disturbances	20	9.3%
Cancer and reasonable suspicion of brain involvement	13	6.0%
Severe sudden ("clapping") headache,	13	6.0%
Concomitant anticoagulation treatment	12	5.6%
Recent brain surgery	9	4.2%
New headache in patients with a known brain tumor	6	2.8%
Presence VP shunt and high suspicion of malfunction	5	2.3%
Known AV malformation	3	1.4%
High fever or suspected meningitis or encephalitis	3	1.4%
Others	19	8.8%
Notes: *In which the anamnesis suggested a suspicion of intracranial hemorrhage; CT = computerized tomography; ED = emergency department; VP = ventriculoperitoneal; AV = arteriovenous;		

DISCUSSION

The continuously growing financial strains on the healthcare system in Israel compels hospital administrators and medical staff to contemplate creative ways to improve efficiency without compromising medical care quality. The extremely long waiting times described in Table 1 result in stressful working conditions and therefore prone to errors (Weigl et al., 2016). Thus, we may conjecture that

medical care quality and efficiency are mutually beneficial such that even incremental improvements in efficiency will result with better medical outcomes.

Modifying the ED workflow for specific complaints is not new. Wang et al. (2015) examined CT-related workflow timelines with respect to customers presenting with acute abdominal pain. They, too, found evidence that CT workflow is an important contributor to ED LOS. However, they did not propose specific ways to improve it. A more recent study of patients presenting with abdominal pain (Begaz et al., 2017) examined the benefit of referring patients from the ED waiting room directly to laboratory and imaging testing. They found that it improves LOS by 31 minutes (95% CI 16 to 46 minutes). Our suggestion for early nurse triage is in line with Arya et al. (2013) who implemented a change in which patients with emergency severity index 3 were split into two groups (high and low variability). They found a 5.9% decrease, from 2.58 to 2.43 hours (95% CI = 4.5% to 7.2%) in LOS.

Our analysis shows that for patients presenting with headaches a change in the typical "triage nurse → physician → CT → physician/discharge" structure may offer considerable savings in waiting time. These patients spend, on average, 396 minutes in the ED (Table 1). Eliminating duplicate wait for a physician will subtract, on average, 121 minutes from their LOS.

To take advantage of these potential savings we propose three alternative modifications to the current treatment of these HP patients. The first suggestion is to qualify the triage nurse to order a CT scan for selected patients presenting with headaches according to a strict set of guidelines. In fact, a similar approach was adopted by the SMC ED for patients presenting to the ED with a high suspicion of stroke. Those patients are sent by the triage nurse immediately to a non-contrast head CT before seeing a physician. To apply this approach for HP patients it is necessary to develop a list of guidelines that will allow the triage nurse to easily determine which patients should be forwarded to CT upon arrival. The obvious limitation of this work design is the difficulty of formulating optimal nurse-oriented guidelines. In the sample of 536 patients from *CT Patients* we found that in 60% (321 of 536) of the cases, the physician did not describe a clear medical indication for referral, suggesting the decision is strongly influenced by the clinical impression of the physician, and not only by objective indications. Therefore, if guidelines were to be restrictive and include only absolute clear indications, they would exclude many of the cases. On the other hand, more inclusive guidelines may result in an excess number of unnecessary CT orders. Beyond the economic burden and the limitation of CT time in the ED, there are serious ethical and medicolegal concerns associated with the risk of having patients exposed to potentially unnecessary radiation. Therefore, guideline-based nurse CT referrals for patients presenting with a headache may be impossible to implement in the ED.

A second possible modification is to assign a fast-track status for patients presenting with headaches, so they could reach the internist immediately after the triage nurse to evaluate the necessity of a CT scan. In SMC ED a fast-track status is given to selected patients by the triage nurse, to avoid the long ED queues. It includes not only relatively urgent patients but also patients who have spent a long time in other EDs in SMC (such as the gynecology or the ophthalmology EDs). Granting a fast-track status to patients presenting with a non-traumatic headache would avoid the multiple waiting times to see physicians for these patients. This suggestion does not save physician time but sidesteps the limitations of the previous suggestion, namely that a qualified physician determines the need for a CT. On the other hand, this modification increases the load in the fast-track lane and may adversely affect its functionality. It would be unjustified to delay an urgent case to save waiting times for patients with headaches of whom the great majority have benign tension headaches (i.e., muscle contraction, secondary to another known illness, migraine, see Leicht, 1980).

The third proposed structural modification is to allocate one of the ED physicians to be adjacent to the triage nurse. The physician will retain his role as an ED physician and will be available to the nurse to assess the necessity of a CT scan when a patient presents with headache as a chief complaint. In a sense, this proposal captures the benefits of the previous two proposals without suffering their disadvantages. The main purpose of the triage physician is to address patients at risk, but

this could also include an assessment of the necessity of a CT scan for patients presenting with a headache. Thus, almost all patients that will eventually undergo a CT will be detected at the triage stage. Moreover, a trained physician is not expected to send unnecessary referrals to CT exams, and therefore the number of CT's performed is not expected to rise. The time the triage physician devotes to evaluate the necessity of a CT scan is very short since the actual patient-physician meeting will take place only later when the patient's turn in the queue arrives. Therefore, the change in the triage physician's work structure is minimal and this proposal's cost in terms of physician time is negligible.

Placing a physician alongside the triage nurse is not a new idea (Rowe et al., 2011). The addition of an attending physician to the nurse triage had a positive impact on LOS in some studies (Burström et al., 2016; Chan et al., 2005; Cheng et al., 2013; Holroyd et al., 2007; Nestler et al., 2012), but the overall effect is not clear (Han et al., 2010; Lauks et al., 2016; Subash et al., 2004). For example, Canadian studies of an ED with 45,000 annual patient visits found that a physician-nurse supplementary triage assistance team reduced delays and left-without-being-seen rates (Cheng et al., 2013) but is not cost-effective, though it may be feasible during time periods with higher patient volume (Cheng et al., 2016). Recently, a study from Switzerland (Oliveira et al., 2018) assessed the impact of a patient-flow physician coordinator, which was allocated from existing staff with no additional resources by comparing two time periods before and after introducing the physician coordinator. The study found no significant difference in LOS between the two time periods. Nevertheless, our proposed model differs from other models of patient-flow physician coordinator that dedicate the physician to the triage process. In our proposal, the triage is performed by the nurse, whereas the physician remains to function as a regular ED physician. The physician, however, helps the nurse only in performing tasks that are either urgent or significantly time saving. Second, the triage physician in the Swiss study focused on a subset of patients who could not immediately be admitted to the emergency room and were first admitted to its waiting room instead, while in our proposition the physician focuses on all walk-in patients. Third, our proposal does not add a physician to the triage nurse. Rather, it limits the physician's interference to cases where his intervention is expected to be cost-effective. Nevertheless, a limitation of our proposal is that its efficiency depends heavily on the experience and capabilities of the triage physician because the position requires quick decisions and high multi-tasking abilities. In the absence of these abilities the triage physician would function as a regular ED physician, which would miss the purpose of placing him next to the triage nurse, or even result in over-prescribing radiological examinations.

Our study shows that most of these wasted hours take place during the afternoon and evening hours (see Figure 3). Consequently, any modification in the work structure design should be limited to those hours – between 14:00 and 24:00.

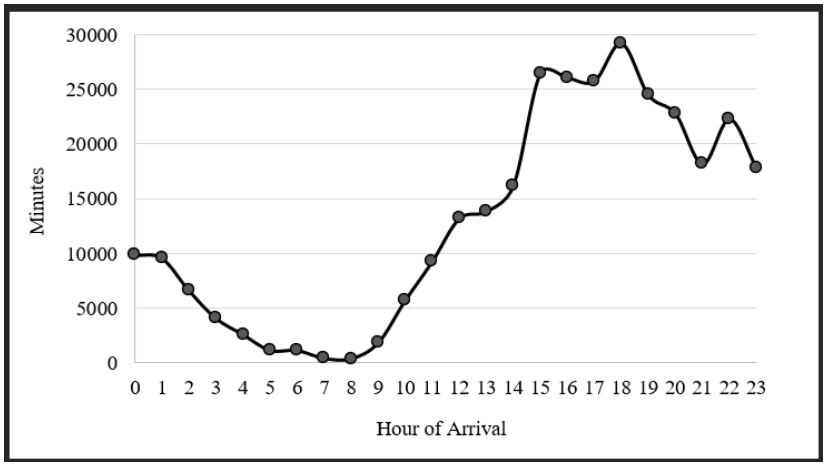

Figure 3: Total potential savings for headache patients requiring CT by hour of arrival

This approach was adopted during the peak hours in SMC ED and was extended to other common complaints, where an early physician triage may save waiting time by ordering imaging or referring to a specialist. With the growing and the aging of the Israeli population the workload volume in SMC ED is expected to continuously increase. It is possible that further expansion in workload will expand the timeframe where the change in workflow is cost-effective.

LIMITATIONS AND CONCLUSIONS

Our study is based on recorded files and reality may differ than the recorded data, in cases of computer problems or retrospective reporting. However, this difference is trivial because computer problems were extremely rare in the study period (three such events were recorded), and retrospective reporting is rarely performed in walk-in patients.

Another limitation of our study relates to the lack of adherence to clinical guidelines regarding indications to order a head CT. The International Headache Society published a classification of headache disorders that has been used successfully to differentiate primary from non-primary headaches (Munoz-Ceron et al., 2019). Despite that, we found in our cohort (unpublished data) that most physicians order unnecessary CT scans. It is possible that if the appropriate guidelines will be practiced in the ER by all physicians, the number of CT scans will be reduced to a point where the structural modification will not be cost-effective. Nevertheless, the benefit of waiting time reduction per patient remains, and an experienced triage physician may help in implementing adherence to good clinical practice. Another important limitation of our study is the absence of cost estimation. To convince decision makers, a reliable cost-effect calculation of the structure modification should be performed (Miake-Lye et al., 2018). This was very difficult to perform in our study since the cost of a triage nurse or physician depends on many variables. Also, while reducing waiting times is an important outcome, it is difficult to assess the cost reduction of this outcome. Nevertheless, our proposition allocates a physician with minimal interruption to his or her position as a regular attending ED physician and there is no expansion in staff or an expected increase in expenses.

Our study analyses the ED timelines of approximately 200,000 patients presenting a period of almost three and a half years. Our goal was to analyze a specific complaint and investigate whether altering the workflow of patients presenting with this complaint may result in a shorter LOS.

Altogether, our study shows how structural modifications to current practice in the ED may increase medical care efficiency by allowing time-saving interventions early in the chain of care for selected chief complaints, such as non-traumatic headache. We show how advanced analysis allows us to locate areas susceptible to consumption of time and resources, measures the extent of the problem, and allows appreciating the cost-effectiveness of future structure modifications. Hopefully, the computerizing of ED's throughout the world will help advance efficiency in the future amidst the growing demand for medical resources.

This study was conducted in Israel whose healthcare system is a hybrid of universal public services and thriving private sector (Clarfield et al., 2017). It would be interesting to examine where its unique healthcare setting affects how ED rooms in Israel operate and compare with countries that are either more privatized or public.

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AUTHORS

Dr. Eitan Giat (MD PhD) is a senior rheumatologist in Sheba Medical Center. He received his MD from the Hebrew University and Hadassah School of Medicine and a PhD in immunology from The Feinstein Institutes for Medical Research. Dr. Giat also works frequently in the emergency department in Sheba Medical Center as an internist. His focus of research extends from inflammation and the immune system, bioinformatics and optimizing patient management.

Dr. Michael Dreyfuss is a tenured faculty member in the Department of Industrial Engineering and Management in the Jerusalem College of Technology. He holds a Ph.D. and an MSc. in Industrial Engineering from the Ben Gurion University of the Negev, a B.Sc. in Computer Sciences and B.Sc. in Industrial Engineering and Management from the Jerusalem College of Technology.

Dr. Yahel Giat is an associate professor in the Department of Industrial Engineering and Management at the Jerusalem College of Technology. He holds a Ph.D. and an MSc. in Industrial Engineering from the Georgia Institute of Technology, an MSc. in Economics, a B.Sc. in Electrical Engineering, and B.A. in Computer Sciences from the Israel Institute of Technology.