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Real-time location systems (RTLS) such as radio frequency identification (RFID) have been shown to improve safety, save cost, and increase patient satisfaction in a healthcare setting especially in the emergency department (ED). Hospital administrators have realized the potential of these applications for improved workflow and operations and are positively adopting it despite the substantial implementation costs of such technologies. Our group has reported several studies with RFID data in the ED showing the relationship between RFID determined patient contact times and length of stay (LOS). In this study, we use ED RFID data to determine the relationship between the total LOS in ED to the overall patient satisfaction obtained from a survey report. ED survey results from 35 questions were obtained from patients after discharge. An observational cohort study was performed in the ED using RFID data from Jan 1 – Dec 31, 2017 matched with the ED survey participants. A total of 2595 survey data was used for logistic regression analysis with the RFID data. Results show that higher treatment LOS influenced overall patient satisfaction negatively. The results provide new insights into designing ideal patient-care team interactions to reduce overall LOS while providing optimal ED care, thereby improving patient satisfaction.

Keywords: emergency department, patient satisfaction, RFID, length of stay.

1. INTRODUCTION

Emergency Department (ED) is a complex care delivery environment that provides time sensitive urgent and lifesaving care [1]. ED presents an unscheduled practice due to the chaotic and uncertain demands of the patients, therefore healthcare providers experience extreme fluctuations in their workload. ED crowding is a major concern that affects the efficacy of the ED workflow, which often is challenged by long wait times, overuse of observation units, patients either leaving without being seen by a provider and non-availability of inpatient beds to accommodate patients after diagnosis [2]. These parameters tend to increase the total length of stay (LOS) of patients with respect to ED capacity [3] and often affect the overall patient satisfaction of the patients upon discharge and have been an ongoing concern for ED healthcare administrators. It is evident that identifying key workflow dynamics in ED can help reduce ED crowding and improve patient satisfaction.

While several methodologies are being tried to better understand ED workflow dynamics to subsequently improve patient satisfaction, use of electronic health records (EMR) and patient satisfaction surveys have been a common practice to better understand the gaps to optimize care and patient

satisfaction. Several studies reveal that EMR adoption has not resulted in significant ED workflow improvements nor reduced the cost of ED operations, with no evidence of direct improvement of patient satisfaction [4]. Since raw EMR data does not offer operational and clinical decision making insights, advanced EMR data analytics are often sought to derive actionable intelligence from EMR data that can indeed improve ED workflow and patient care satisfaction. However, no significant strides have been made in optimizing ED workflow that reduces overall LOS and improves patient satisfaction, as the challenges continue to remain with ED workflow issues. Several groups through survey analysis have reported ED patient dissatisfaction due to high LOS [5], ineffective communication to patients about wait times and queue [6-8], and longer wait times [9]. A comprehensive literature review of ED patient satisfaction experience points to three main factors influencing satisfaction: staff-patient communication, ED wait times, and staff empathy and compassion. These factors warrant novel research to dissect characteristics of ED patient experience themes which can allow novel insights into designing interventions to address patient satisfaction issues [10].

Radio Frequency Identification Device (RFID) is a wireless automatic identification and data capture technology device that has the potential for improving safety, preventing errors, saving costs, and increasing security which therefore improves overall organizational performance. RFID technology use in healthcare has opened a new space in healthcare informatics research that provides novel data to identify workflow process pitfalls and provide new directions [11]. The potential advantages of RFID adoption in healthcare, especially in ED, has been well recognized to save costs and improve care delivery [12]. However, the large upfront infrastructure costs, need for an integrated health information technology (HIT), advanced analytical tools for big data analysis emerging from RFID, and skilled data scientists to tackle the data to derive actionable intelligence discourage many hospitals from adoption RFID technology despite its potential advantages.

RFID adoption in the ED at the Saint Mary's Hospital at Mayo Clinic, in Rochester, MN, occurred in August 2015 as a step towards optimizing ED workflow [13] and improve patient care thereby improve patient satisfaction. Our recent studies on the RFID data analytics demonstrated the feasibility of quantifying and analyzing two novel variables such as 'patient alone' time defined as the total time a patient spends alone without interaction with a health care staff in the ED and 'provider contact time' defined as the total time a patient spends interacting with any health care staff [14]. The study demonstrated novel insights into ED workflow in terms of ED staffing (physicians, nurses, physician assistants, and residents), factors influencing ED LOS that can potentially improve the quality of care in the ED and also reduce cost [15]. However, to date, no work has been done to explore the direct relationship between RFID determined total ED LOS and overall patient satisfaction that can provide new themes of ED satisfaction

research which can be potentially resolved using RFID data analytics. Therefore, the purpose of this work was to determine the influence of RFID based total LOS on overall patient satisfaction determined from ED survey data that will wide open patient satisfaction research for continuous improvements.

2. MATERIALS AND METHODS

2.1 Study Design and Setting

In this work, an observational cohort study design was used to evaluate the relationship between total LOS determined from RFID and overall patient satisfaction from ED survey data at the ED in Mayo Clinic, Rochester, MN USA. The ED is equipped with an RTLS since August 2015 that uses passive RFID technology (Quake Global, Inc, San Diego, CA 92123, United States)

2.2 Selection of Participants

The study population was all ED patients placed in an acute care room between Jan 1 and Dec 31, 2017, excluding pediatric and behavioral health patients. RFID data that matched with survey results obtained from patients in this time window were used for analysis.

2.3 RFID Measurements

Timestamp data from the RFID tag is detected within the coverage area of an RFID reader throughout the ED and stored in a database for analysis. Primary RFID data analysis includes determining the entry and exit time of a patient or an ED staff during the care time. Using these timestamp data, we calculate the total LOS of the patient for this study purpose.

2.4 ED survey data collection and analysis

ED survey questionnaire is mailed out to patients who received ED care at Mayo Clinic and were discharged. The primary purpose of this survey is to obtain patients overall experience and satisfaction towards the quality of ED care for continuous improvements. The survey consist of 35 total questions spanning from basic patient background, quality of care received, and questions that gauge their specific and overall satisfaction of the care they received. Survey data from those patients who completed and sent back were obtained and digitally stored for analysis. For the purposes of this work, the EMR, RFID, and patient satisfaction data were linked to perform the proposed comprehensive analysis.

2.5 Statistical Analysis

We performed multivariate logistic regression adjusted for age, sex, ED pod, arrival month, arrival day, disposition type, and comorbidities to study the relationship between LOS and overall patient satisfaction with respect to specific providers such as physicians, nurses, residents and physician assistants. Open source R-studio was used for all analysis. P values less than 0.01 was considered significant for this study.

3. RESULTS AND DISCUSSION

Linking of the three databases such as RFID, EMR and patient satisfaction resulted in a total of 2595 observations for analysis. Table 1 shows the basic demographics of the data used for analysis in this study.

Table 1: Basic Demographics of patient data

	Overall (N=2595)
Admit date	
Median	2017-07-01
Range	2017-01-01 - 2017-12-31
Race	
African	8 (0.3%)
American Indian or Alaska Native	10 (0.4%)
Black or African American	34 (1.3%)
Chinese	6 (0.2%)
Japanese	2 (0.1%)
Korean	2 (0.1%)
Native Hawaiian	3 (0.1%)
Other	44 (1.7%)
Other Asian	22 (0.8%)
Unknown	6 (0.2%)
Vietnamese	1 (0.0%)
White	2457 (94.7%)
Age group	
18-34	270 (10.4%)
35-49	417 (16.1%)
50-64	849 (32.7%)
65+	1059 (40.8%)
ED location	
ADULT ED ACUTE	2359 (90.9%)
ADULT ED OBSERVATION	236 (9.1%)
language	
ENGLISH	2592 (99.9%)
SPANISH	3 (0.1%)
Age	
Mean (SD)	59 (17)
Range	18 - 96
Sex	
Female	1519 (58.5%)
Male	1076 (41.5%)
Person filling out survey	
Missing	71
Family	80 (3.2%)
Friend	1 (0.0%)
Other	16 (0.6%)
Parent	23 (0.9%)

	Overall (N=2595)
Patient	2404 (95.2%)

As seen from Table 1, the dataset represent a reasonable spread across various age groups, race, gender and person filling out the survey data. Table 2 shows a representative logistic regression analysis results with respect to the overall satisfaction of patients based on care provided by a physician.

Table 2: Logistic regression analysis showing factors influencing overall patient satisfaction based on physician provider

term	estimate	p.value
age.group35-49	-0.041	0.86
age.group50-64	0.186	0.38
age.group65+	1.043	0
ESILevel 2	-11.545	0.99
ESILevel 3	-12.026	0.99
ESILevel 4	-12.187	0.99
ESILevel 5	-13.116	0.99
podCENTER2	0.126	0.51
podEAST	-0.239	0.28
dispoTypeDischarge	-2.080	0.042
dispoTypeHospital Observation	-1.946	0.13
dispoTypeLeft Before Treatment Complete	10.494	0.99
dispoTypeSend to OR	11.151	0.99
dispoTypeTransfer to Health Care Facility	-19.943	0.98
cormobidity_count	0.079	0.3
LOS	-0.203	0

As seen from Table 2, factors such as age group over 65, disposition type pertaining to discharge and overall LOS were strong factors influencing overall patient satisfaction with analysis restricted to physician. Similar results were obtained with specific analysis for nurses, residents, and physician assistants. The results indicate LOS being the strongest factor that influence overall patient satisfaction i.e. longer the LOS lower satisfaction as reported by the patients. This result is as expected because the patients anticipate quick urgent care and relief expect being discharged without too many delays that is manifested in the total LOS. The negative association implies that many factors in ED workflow that cause higher LOS needs careful investigation to reduce LOS which has been an ongoing ED optimization problem without a practical solution. Also, results suggest patients older than 65 and discharge term influence patient satisfaction levels.

In this work, we used RTLS data in ED to study the influence of LOS on overall patient satisfaction of patients who received ED care. In general, it is expected that higher LOS will result in

lower patient satisfaction. The analysis confirmed this hypothesis. However, the results suggest the need to further dissect the reasons behind longer LOS to reduce the time inefficiencies in ED. As evident in literature, ED crowding, inefficient ED staffing plans and resource sharing, unexpected increased ED waiting times etc. are among those that cause higher LOS. As reported in our previous studies, RFID data analytics can be the potential direction for increased process visibility and workflow dynamics in ED that can address these ED challenges to reduce LOS which in turn can improve ED patient's experiences and satisfaction while providing optimal care.

As reported in our previous work, patient care team contact time (PCTCT) measurements can provide greater insights into addressing efficient ED staffing to maximize care and reduce total care time [16]. Also, investigation into factors causing higher total patient alone time in ED using RFID data can provide insights into approaches to improve patient satisfaction by counteracting delays and higher wait times.

The results of this study highlight the importance of RFID data analytics to provide a novel perspective into addressing patient satisfaction that was not possible before. Future work that integrates RFID based patient-care team interactions, patient alone times and ED staffing can shed light into providing new tools and guidelines for improved patient engagement and outcomes in the ED, which subsequently can improve patient satisfaction.

4. CONCLUSION

RFID based higher total LOS negatively influences overall patient satisfaction in the ED that warrants to identifying and resolving the factors that lead to higher LOS in the ED. In this context, RFID data and analytics provides a novel platform complimentary to EMR and survey data analytics by providing better process visibility into ED workflow to identify factors that can improve patient satisfaction.

Future work will focus on a more integrative data analytics approach to dissect the contributions of patient provider times, patient alone times, ED staffing, and other dynamic parameters using RFID data to provide a comprehensive framework to improve overall ED care and therefore patient satisfaction.

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