# Apply Visual Analytics for Insight and Effective Strategy Development to Reduce Frequent Emergency Department Use

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## Abstract

**Background:** Frequent hospital emergency department (ED) use has been increasing. The objective of this study is to analyze frequent ED use at a large NYC public hospital and to provide insight for effective intervention strategy development to reduce frequent ED use.

**Methods:** A cohort of 775 (1% of all ED users, 11% of total ED use) frequent users with 10+ ED use per year was focused. Demographics, insurance, medical/mental problems and use of other hospital services were studied. Visual analytics was utilized for insight discovery and visualization.

**Result:** 79% of this cohort were insured, 49% had primary care physicians but only visited once on average. Further break-down reveals different hospital service use patterns. Most also had higher utilization of acute and specialty clinics, while another group mainly utilized ED. More than half of the cohort suffer substance abuse and behavior health problems. Homeless had significant higher utilization of ED. The results reveal frequent ED users had unmet needs that could not addressed in other services but turned to ED for help.

**Conclusion:** Analyzing determinants of individual health is essential for better understanding root causes of frequent ED use. Developing personalized intervention strategy is crucial to address those different unmet needs beyond scope of ED and healthcare services. Improving primary care access, health literacy education, collaborative partnership with other community and human services are critical to reduce frequent ED use. The study also demonstrates visual analytics is an efficient approach to help care providers for insight discovery and effective strategy development.

**Keywords**: emergency department, frequent ED use, visual analytics, personalized intervention

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## 1. Introduction

Frequent hospital emergency department (ED) use has been increasing even after more people received health insurance and access to primary care continuously improved [1]. The 1986 Emergency Medical Treatment and Labor Act (EMTALA) federal law requires anyone coming to an ED to be stabilized and treated, regardless of their insurance status or ability to pay [2]. EMTALA helps prevent hospital from denying care or turning the frequent ED users away, making ED the only place in the U.S. health care system. Therefore, ED is stressed to provide prompt and high quality treatment for patients with urgent and emergent medical problems while coping with many challenges including overcrowding, long wait time and misuse of ED case for non-urgent problems. Not all frequent users treat ED as a substitute of primary care. Some in fact are less healthy population who need and use more care overall and other human and social services. Recent research [3] indicates that frequent ED users have a substantial burden of disease, and they have high rates of primary and specialty care use. They also have linkages to outpatient care that are comparable to those of other ED patients. Many states including New York State (NYS) have taken steps to reduce avoidable ED use. The NYS Delivery System Reform Incentive Payment (DSRIP) Program [4] requires participating public safety net hospitals to reduce avoidable hospital use (including ED use) by 25% over 5 years from 2016 to 2020.

In order to successfully reduce avoidable ED use, it is essential to identify the factors and determinants of health influencing rate of ED use [5], and to understand multifaceted root causes of frequent ED use and determine gaps in the delivery of health services. Those various unmet needs that drive patients back-and-forth to the ED frequently are clearly beyond medical problems and scope of ED. The complex challenge calls for a much broader collaborative program among hospitals, community services, and other social and human services. Personalized intervention strategy needs to be developed to motivate the frequent ED users taking active role in lifestyle change. The effective intervention and collaboration will help optimize the use of ED in general, as well as achieve better outcome for those individuals who frequently use the ED. The purpose of this study is to provide insight for care providers, practice administrators and health policy makers through a case study at an emergency department in a large New York City public hospital to better understand the frequent ED use patterns and help reveal underlying reasons of different frequent user groups. An effective intervention strategy to reduce frequent ED use needs an efficient enabler to dynamically integrate data from multiple sources include clinical, social economics, insurance, and other data service providers. Traditional business intelligence platform and service model no longer fit the scale of healthcare big data and pressing needs from care providers and administrators. The new generation visual analytics tools, such as Tableau, are proven to be able to provide on-demand, scalable interactive insight discovery and performance metrics. The dataset and methodology used in this study are introduced in section 2. Results and findings are discussed in section 3. Limitation and future research are summarized in section 4.

## 2. Data and Method

The data used in this study came from the electronic medical record system at a large New York City public hospital. The emergency department of this inner-urban hospital is one of the busiest in the country with over 173,000 annual ED visits [6]. Majority of patient population are socioeconomic challenged New Yorkers including low-income, uninsured, homeless and undocumented immigrants. The public safety net hospital is committed to extend quality care equally to all New Yorkers regardless of their ability to pay. The 24x7 open emergency department at the hospital becomes a gateway to health care for this vulnerable population.

While there have been a broad range of research on frequent ED use, there is no common definition on the qualifying number for frequent ED use. It could range from as few as 3 visits to 12 or more annually [7]. In this study, ED use by all adult patients (aged 21 and older) during a 12-month period (July 2015 to June 2016) was retrieved from the electronic medical record system. Table 1 shows the number of distinct ED patients and visits grouped by use frequency during last 12 months. A cohort of 775 patients (10+ ED use) stand out because this 1% of total distinct patients account for 11% of total ED use in last 12 months. Therefore, the focus of this study was set on this particular group of frequent ED users with 10 or more ED visits in last 12 months.

Additional comprehensive data were retrieved from the electronic medical record system including demographics, insurance status, ED arrival time, Emergency Severity Index (ESI) level, disposition, medical problems, substance use and behavior problems, and their use of other hospital services (inpatient, primary care and specialty care clinics) during the same time period.

To help provide better understanding on the frequent ED use pattern and the contributing impact factors, Tableau visual analytics application [8] was used for insight discovery, data analysis and information visualization. Visual analytics is the science of analytical reasoning facilitated by interactive visual interface [9]. Tableau enables provider-driven interactive visual exploration of big data from electronic medical record system. In this study, visual analytics dashboard examples are included in the following section to demonstrate how Tableau helps transform ED visit data into actionable insight.

Table 1 ED Use Frequency by Adult Patients (aged 21 and older) during 12-Month Period

| Number of ED Visits in 12 Months | Number of Distinct Adult ED Patients | Number of Adult ED Visits | % of Total Adult ED Patients | % of Total Adult ED Visits |
|---|---|---|---|---|
| 1 | 48,499 | 48,499 | 65.4% | 35.3% |
| 2 | 13,666 | 27,332 | 18.4% | 19.9% |
| 3 | 5,538 | 16,614 | 7.5% | 12.1% |
| 4 | 2,610 | 10,440 | 3.5% | 7.6% |
| 5 | 1,357 | 6,785 | 1.8% | 4.9% |
| 6 | 769 | 4,614 | 1.0% | 3.4% |
| 7 | 487 | 3,409 | 0.7% | 2.5% |
| 8 | 271 | 2,168 | 0.4% | 1.6% |
| 9 | 216 | 1,944 | 0.3% | 1.4% |
| 10+ | 775 | 15,551 | 1.0% | 11.3% |
| Grand Total | 74,188 | 137,356 | 100.0% | 100.0% |

## 3. Results and Discussion

Using Tableau interactive visual analytics tool, different patterns were revealed when the cohort of 775 frequent ED users were further classified into sub-groups as follows:

- Group #1: 10-19 ED visits in 12 months
- Group #2: 20-29 ED visits in 12 months
- Group #3: 30 or more ED visits in 12 months

Figure 1 and Table 1 show most of the frequent ED users fall into Group #1 (10-19 ED visits) and account for most of ED visits (47%). Group #3 (30+ ED visits) has only 89 patients but they made almost comparable amount (38%) of ED visits as Group #1 in the 12 month period. Although the 101 patients in Group #2 (20-29 ED visits) had significant frequent ED use individually, they made 15% of the total ED visits in the same time period.

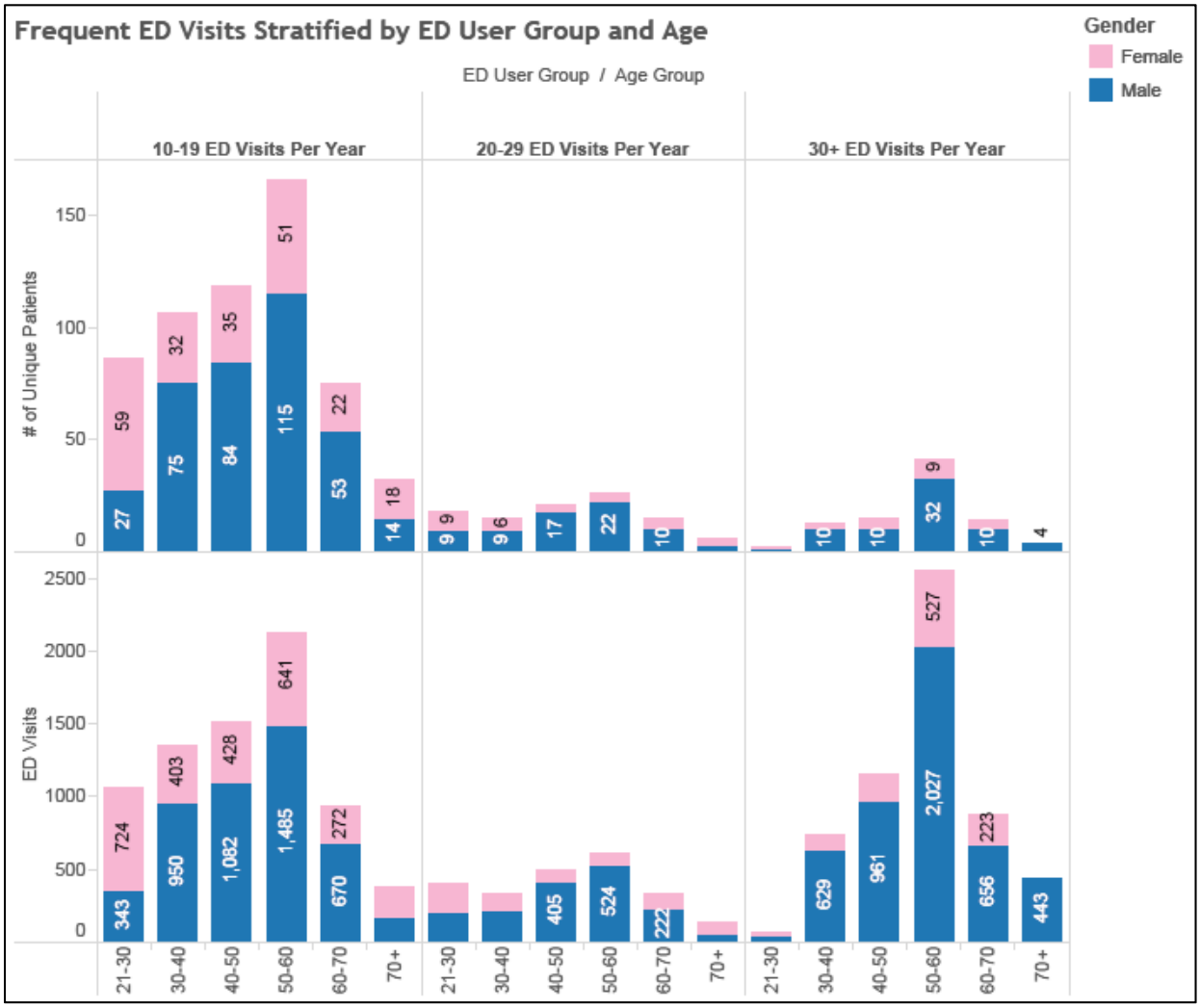


Figure 1 ED Visits by Frequent ED Use Sub-group and Age Group

Figure 2 demonstrates different patterns in use of other hospital services by each sub-group. Group #1 frequent users are overall younger than Group #2 and Group #3. With more female frequent ED users, Group #1 also utilized other hospital services including inpatient, primary care clinics and specialty care clinics, especially women's health services which do not require referrals from primary care physicians. But their use of primary care in this hospital is low with average only 1 visit per patient in 12 months, even though they appeared to use more specialty clinic services. Group #2 and #3 have much fewer frequent ED users than Group #1 and did not utilize much use of other hospital services. The key difference between

Group #2 and #3 is that most of patients (aged 50-60 years old) in Group #3 had significantly higher use of ED.

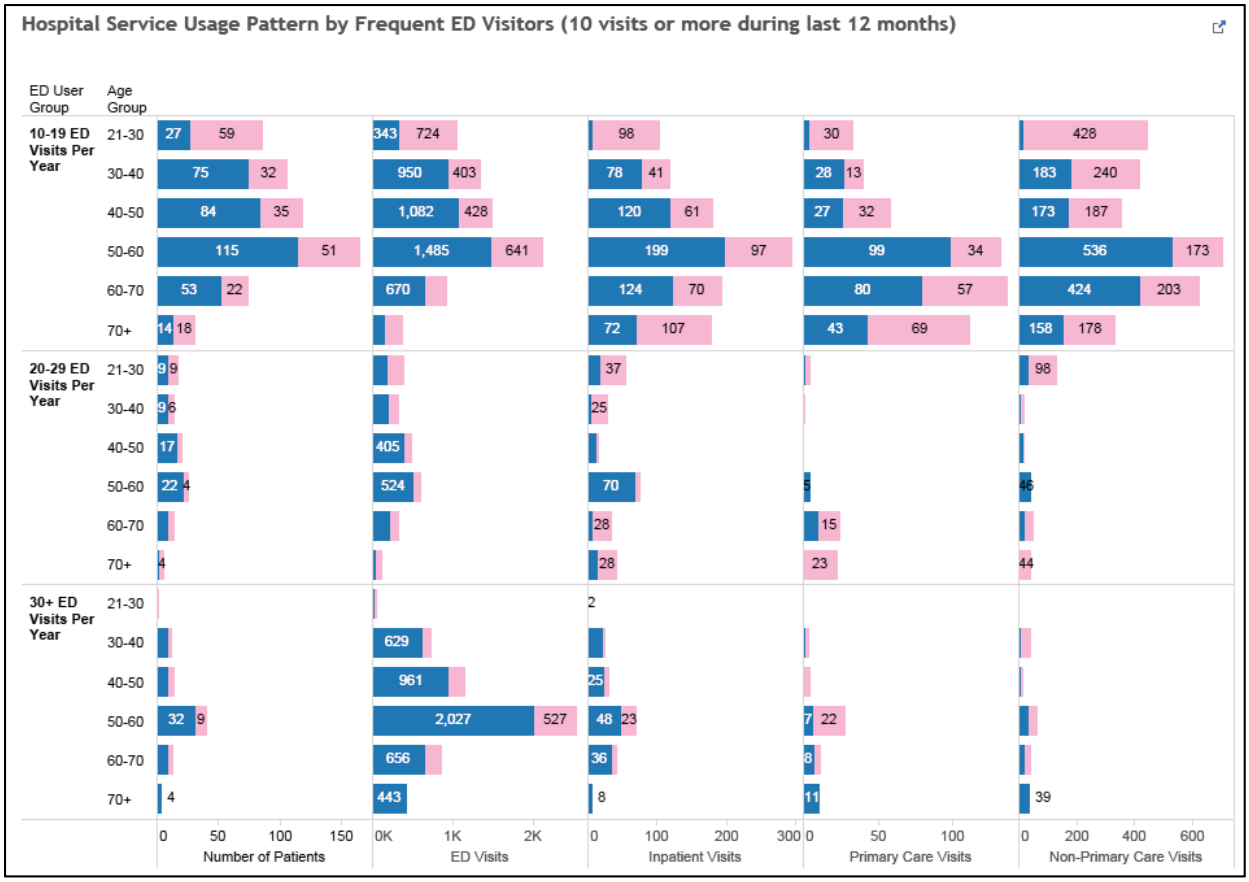


Figure 2 Other Hospital Service Usage Pattern by Frequent ED Visitors

Different patterns may reflect distinct patient needs. Table 2 summaries demographics and other key characteristics of each frequent ED use sub-group. With interactive exploration on the comprehensive data set using Tableau visual analytics tool, further insights were discovered.

Table 2 Demographics and Hospital Service Use Pattern of Frequent ED Visitors

| Frequent ED Visit Group Count n (% of total) | | Group 1 10-19 ED Visits Per Year | Group 2 20-29 ED Visits Per Year | Group 3 30+ ED Visits Per Year | Total |
|---|---|---|---|---|---|
| **Patient** | Total (%) | 585 (75%) | 101 (13%) | 89 (11%) | 775 |
| | Male | 368 (73%) | 69 (14%) | 67 (13%) | 504 |
| | Female | 217 (80%) | 32 (12%) | 22 (8%) | 271 |
| **Insurance** | Insured | 462 (75%) | 82 (13%) | 70 (11%) | 614 |
| | Uninsured | 123 (76%) | 19 (12%) | 19 (12%) | 161 |
| **PCP** | Has PCP | 290 (77%) | 45 (12%) | 41 (11%) | 376 |
| | No PCP | 295 (74%) | 56 (14%) | 48 (12%) | 399 |
| **Substance** | Substance abuse | 294 (69%) | 63 (15%) | 71 (17%) | 428 |
| | No substance abuse | 291 (84%) | 38 (11%) | 18 (5%) | 347 |
| **BH/Psych** | BH/psych problem | 317 (71%) | 59 (13%) | 72 (16%) | 448 |
| | No BH/psych problem | 268 (82%) | 42 (13%) | 17 (5%) | 327 |
| **Homeless** | Domiciled | 551 (79%) | 88 (13%) | 62 (9%) | 701 |
| | Undomiciled | 34 (46%) | 13 (18%) | 27 (36%) | 74 |
| **ED** | Total visits | 7,380 (47%) | 2,337 (15%) | 5,834 (38%) | 15,551 |
| | Average visits | 13 | 23 | 66 | 20 |
| **Inpatient** | Total visits | 1,074 (71%) | 258 (17%) | 184 (12%) | 1,516 |
| | Average visits | 2 | 3 | 2 | 2 |
| **Primary Care** | Total visits | 516 (81%) | 60 (9%) | 61 (10%) | 637 |
| | Average visits | 1 | 1 | 1 | 1 |
| **Specialty Care** | Total visits | 2,903 (84%) | 323 (9%) | 218 (6%) | 3,444 |
| | Average visits | 5 | 3 | 2 | 4 |

**Health Insurance**

It is worth noticing that 79% of (614 out of 775) frequent ED users have health insurance. Medicaid is the predominant health insurance among these frequent ED users. Although this high percentage rate may seems to be a surprise to conventional belief, it is consistent to previous research [10] that publicly insured adults are 2.08 times more likely to be frequent ED users than privately insured? The high percentage of insured also reflects the positive impact of Affordable Care Act (ACA) on Medicaid enrollment, particularly with the implementation of Medicaid expansion in New York. In fact, Medicaid has become the largest insurer in the United States.

**Access to Primary Care**

Providing health insurance coverage is an important step in improving access to care. However as the data in Table 2 and Figure 2 indicate access to primary care remains a much complex challenge. Low Medicaid reimbursement for outpatient care may severely limit the availability of providers willing to accept Medicaid patients, especially private hospitals and practices. Therefore, access to care for Medicaid patients becomes a choice between an overcrowded outpatient clinic and ED in a public hospital. On the other hand, although 49% (376 out of 775) of frequent ED users had their primary care physicians located in the same

hospital location, they had made only very limited primary care visits during the 12 month period, barely average one primary care visit per person per year.

The common approaches to help reduce ED frequent use have been deployed to improve care access by adding more doctors, expanding primary care office hours and availability of combined primary care and behavior health services. For certain frequent ED users, these may work perfectly, but not for all of them, especially for this particular cohort of frequent ED users in this study. For those undocumented immigrants, ED may be their only source of health care service. Socioeconomic status is a crucial factor influencing the rate of ED use by patients with non-urgent reasons. Patients may come to ED more often for non-urgent reasons due to poor health literacy skills, cultural differences according to health understanding, lack of knowledge about the healthcare system, or inability to make appointments by phone because of limited English language skills. All these factors could be barriers to accessing primary care.

**Less Urgent and Non-Urgent ED Use**

Depending on education and health literacy level, patients and care provides often have different perspectives on urgency. An urgency to a patient may not be perceived as urgent condition by ED care provider. There is always a risk of either under-estimating or over-estimating urgency, which could jeopardize patient care or overcrowded and long stay in ED. It is vital for ED to assign the right patient to the right resources in the right place at the right time [11]. A 5-level ESI scale triage system [12] was used for sorting patients to determine priority of further care at the time of patient arrival in the ED. In this study, 35% of frequent ED users presented with less urgent (ESI 4) or non-urgent (ESI 5) medical needs as shown in the bar chart in Figure 3. The disposition distribution by ESI level in Figure 3 reveals that 63% of these less urgent or non-urgent visits were treated and released; and 31% just walked out voluntarily.

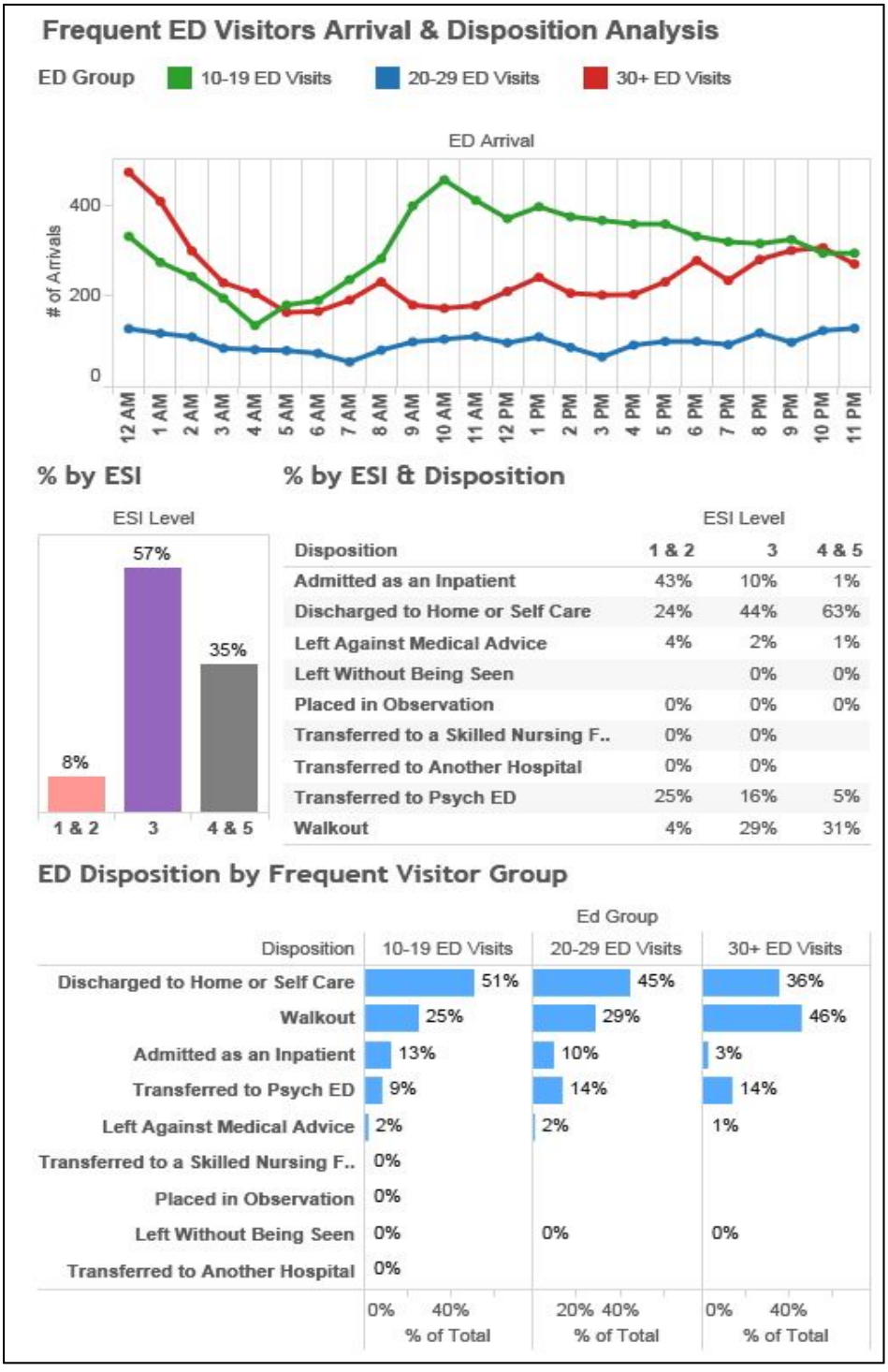


Figure 3 Frequent ED Visit ESI, Arrival and Disposition

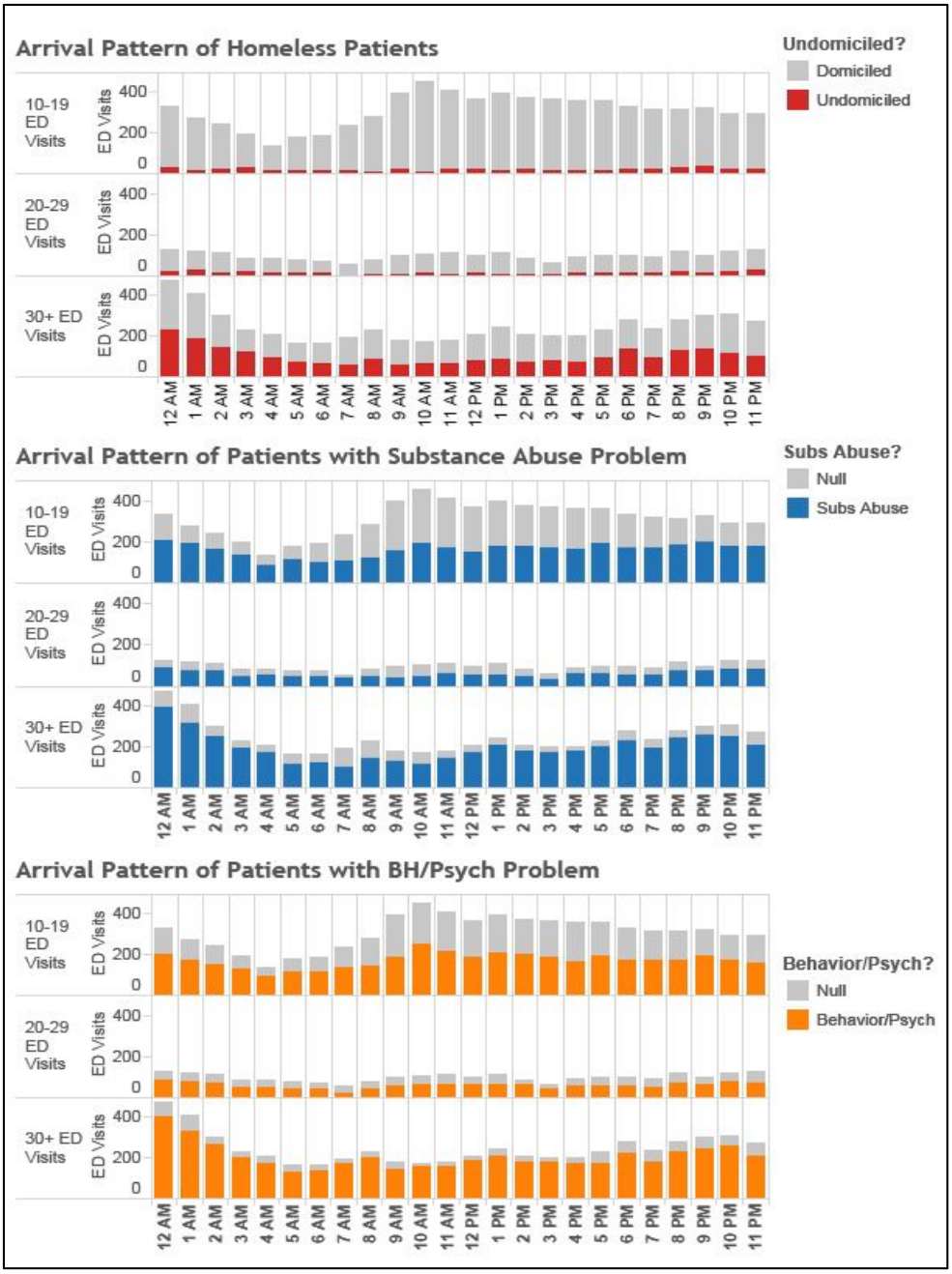


Figure 4 ED Comparison of ED Arrival Pattern by Different Groups

**Substance Abuse and Behavior Health**

Patients with substance abuse and behavior health problems tend to be at greater risk for acute conditions. As illustrated in Table 2, 55% of the frequent ED users have substance abuse problems and 58% have behavior health/psychiatric problems. These percentage rates in this study are much higher than findings in other recent research [2]. In addition to primary care for their medical problems, this group of patients need behavior health clinic services. Their ED arrivals exhibit different pattern from other frequent users as shown in Figure 4 with arrivals peak around mid-night. Most of those diagnosed with chronic alcoholism

repeatedly showed up at ED intoxicated or agitated and had to be transferred to the psychiatric emergency services. Therefore, their frequent ED use also presents greater risk to other ED patients.

**Homeless**

In this study, 74 out of 775 (10% of total) of the frequent ED users were identified as homeless based on their address field and social risk assessment note by social work documented in the electronic medical record system. Many homeless patients also suffer substance abuse and behavior health problems. As illustrated in Figure 4 and Table 2, the 27 homeless patients account for almost half of total ED visits by Group #3 (30+ ED use per year). Their arrivals to the ED typically peak at night. Homeless face multiple competing demands in their daily life, such as medical problems, food and shelter. Poor health combined with limited shelter housing options and unmet needs from other resources may influence going to the ED regardless of the urgency level of medical conditions [13]. Although they feel that the ED is a much safer and comfortable environment than the street and shelters, their true needs could not be provided in an urgent care setting. The homeless need stable housing and other social services.

**Personalized Intervention Strategy to Reduce Frequent ED Use**

Visual analytics of frequent ED use reveals the complexity of the problem that ED and healthcare system alone are not sufficient nor effective to address all the underlying root causes by frequent users. EMTALA helps prevent hospital from denying care or turning these frequent ED users away. The Affordable Care Act (ACA) mandates public hospitals to conduct the Community Health Need Assessment (CHNA). Figure 5 shows an example of visual analysis dashboard map of frequent ED users by zip codes. It helps link community resources, social services and other health and human services working together with health care providers to solve the challenge collaboratively. In order to develop effective intervention strategy to reduce frequent ED use, it is crucial to take a holistic view of all potential determinants to health.

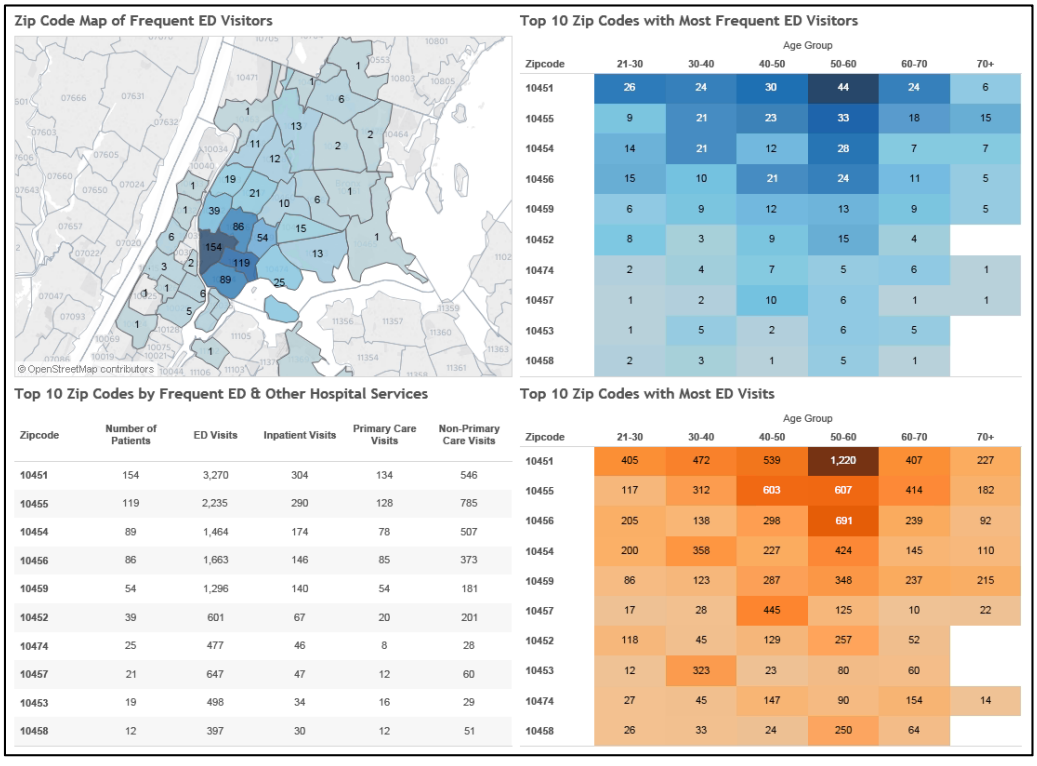


Figure 5 Top 10 Zip Codes with Most Frequent ED Visits

A number of interventions to reduce frequent ED use have been evaluated in the literature [14]. Although case management approach had the most rigorous evidence base but with variable reduction in frequent ED use. Based on the analysis results in this study, a personalized intervention strategy is proposed to reduce frequent ED use. The approach is consistent to the latest concept of P4 medicine [15] which promote Personalized, Participatory, Preventive and Predictive as guideline and encourage patients' active involvement for lifestyle changes and consider all the determinants to individual health.

*Better Understanding on Determinants to Health*

The range of personal, social, economic, and environmental factors that influence health status are known as determinants to health including following categories [5]:

- Policymaking: such as taxes on tobacco sales, Affordable Care Act
- Social and physical environment: such as income, discrimination, housing, exposure to hazards
- Health services: such as access to health services and the quality of health services
- Individual behavior: such as diet, physical activity, alcohol use, injection drug use, smoking
- Biology and genetics: such as age, inherited conditions, HIV status

*Partner with Community and Social Services*

For many frequent users, they had social, interpersonal and mental needs rather than medical needs. EMTALA prevents hospital from denying care or turning these frequent ED users away. Some of the frequent ED users had formed close relationship with the ED staff. They treat the ED as home where they can receive any help. The repeated pattern results in waste of resource and ineffective cycle for both patients and the ED staff because the root causes were beyond the scope of the medical staff. As it appears clearly that ED and healthcare cannot resolve this alone, it is crucial to break down this repeated cycle, understand their determinants of health and address the unmet social and physical environmental needs. For the homeless, collaborative partnership pilot program such as BronxWorks has proved to be effective. BronxWorks is a human service organization and settlement house that feeds, shelters, teaches and supports neighborhood to build a stronger community. For those frequent ED users with alcohol and substance abuse problems, linking them to community activity and treatment centers for personalized, participatory lifestyle changes appears to be helpful in reducing avoidable ED use.

*Health Literacy Program*

Health literacy is the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decision. Study found higher utilization of the ED by patients with inadequate health literacy [16]. The average self-reported literacy proficiency level of the adult patient population at the hospital is equivalent to eighth grade. It is important to develop health literacy education program at hospital and in the community to increase health literacy and to secure equity health care services for specific vulnerable groups. The program will guide frequent ED users with plain language and help them understand how healthcare system works, when to see primary care physician and when to come to ED only for urgent use. They need to understand although few settings outside the ED can provide a parallel level and rapid access of care, the ED is however a costly setting for the delivery of chronic, non-urgent care. The ultimate goal of the personalized interventions focus on changing individual's behaviors to reduce rate of chronic disease. Health literacy skills start early in life. Therefore, all children in the community should graduate with health literacy skills that will help them lead healthiest lives.

*Continuous Improvement Access to Primary Care*

Progress has been made to expand primary care office hours into evenings and weekends. Clinic appointment availability, clinic wait time, visit cycle time are continuously monitored for performance improvement and better patient experience. Additional language interpreters are hired to make it easier for patient navigating through the clinic or making appointment by phone. Primary care physicians and nursing staff also work collaboratively with the ED to follow up with those frequent ED users to get better understanding on their unmet health needs. The DSRIP program will help bring additional momentum to reduce avoidable ED use by making sure patients receive appropriate care and preventive services.

## 4. Conclusion

Determinants of health are critical factors for better understanding on the root causes of individual frequent ED user. Develop personalized intervention strategy for each subgroup, each individual based on different unmet needs which are beyond ED and healthcare services. In addition to improving primary care access, health literacy education, collaborative partnership with community and other human services are critical to the success of the personalized intervention strategy. The results may provide potential useful policy implications in way of developing educational intervention program to increase health literacy and to secure equity health care services for specific vulnerable groups. The study also demonstrates that visual analytics is an efficient approach to help the pressing needs of care providers and administrators for interactive data exploration and insight discovery. The insights gained from advanced visual analytics help drive operational performance. It is essential for leading to well-informed decisions and effective intervention strategies and policies. Cost factors are not integrated into this study which is a limitation and will be addressed in our future research.

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