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A Computerized Pneumococcal Vaccination Reminder System in the Adult Emergency Department

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Abstract

Background—Pneumococcal vaccination is an effective strategy to prevent invasive pneumococcal disease in the elderly. Emergency Department (ED) visits present an underutilized opportunity to increase vaccination rates; however, designing a sustainable vaccination program in an ED is challenging. We examined whether an information technology supported approach would provide a feasible and sustainable method to increase vaccination rates in an adult ED.

Methods—During a 1-year period we prospectively evaluated a team-oriented, workflow-embedded reminder system that integrated four different information systems. The computerized triage application screened all patients 65 years and older for pneumococcal vaccine eligibility with information from the electronic patient record. For eligible patients the computerized provider order entry system reminded clinicians to place a vaccination order, which was passed to the order tracking application. Documentation of vaccine administration was then added to the longitudinal electronic patient record. The primary outcome was the vaccine administration rate in the ED.

Multivariate logistic regression analysis was used to estimate the odds ratios and their 95% confidence intervals, representing the overall relative risks of ED workload related variables associated with vaccination rate.

Results—Among 3,371 patients 65 years old and older screened at triage 1,309 (38.8%) were up-to-date with pneumococcal vaccination and 2,062 (61.2%) were eligible for vaccination. Of the eligible patients, 621 (30.1%) consented to receive the vaccination during their ED visit.

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Physicians received prompts for 428 (68.9%) patients. When prompted, physicians declined to order the vaccine in 192 (30.9%) patients, while 222 (10.8%) of eligible patients actually received the vaccine. The computerized reminder system increased vaccination rate from a baseline of 38.8% to 45.4%. Vaccination during the ED visit was associated younger age (OR: 0.972, CI: 0.953–0.991), Caucasian race (OR: 0.329, CI: 0.241–0.448), and longer ED boarding times (OR: 1.039, CI: 1.013–1.065).

Conclusion—The integrated informatics solution seems to be a feasible and sustainable model to increase vaccination rates in a challenging ED environment.

Keywords (MeSH)

Reminder Systems; Medical Informatics; Pneumococcal Vaccines; Emergency Service; Hospital

INTRODUCTION

Streptococcus pneumoniae infections account for approximately 100,000 – 135,000 hospitalizations annually, and 14% of these hospitalizations result in death¹. Pneumococcal vaccination is cost-effective², primarily reducing the burden associated with invasive pneumococcal disease. However, only 62% of patients 65 years and older are vaccinated against pneumococcal disease³, much below the 90% goal set by Healthy People 2010⁴. The Joint Commission has named pneumococcal vaccination as a core measure⁵.

Each patient encounter with the health care system provides an opportunity to offer preventive care measures⁶. Because the emergency department (ED) accounts for a large proportion of health care encounters, it has been suggested as a suitable environment for a pneumococcal vaccination program^{7, 8}. However the ED is a challenging environment for implementing an effective and sustainable strategy for offering preventive care. The challenges of providing episodic care to an increasing older and sicker population, lacking pertinent patient information, and provider perception of the ED being an inappropriate setting for offering preventive care⁹ are augmented by operational factors such as frequent overcrowding^{10–13}, shortages of nurses¹⁴ and hospital beds¹⁵.

Many patients at high risk for pneumococcal disease frequently seek care in the ED¹¹. Of patients hospitalized with pneumococcal infections, 55% had an ED encounter in the previous five years¹⁶. In the US, only 266,000 patients received a pneumococcal vaccination in the ED¹⁷. An ED-based vaccination program can bridge a missed opportunity^{9, 18, 19}; its implementation is feasible and can increase vaccination rates shown in both retrospective analyses and nurse-driven standing-orders^{7, 16, 20}. However, experiences in the ED setting remain scarce^{19, 21} and require substantial efforts and resources to achieve sustainability²⁰.

Computerized reminders have been successful at increasing vaccination rates in primary care and inpatient settings^{22, 23}; however, they have not been applied in an ED environment. We evaluated the impact of a team-oriented, pneumococcal reminder system that was embedded in the clinical workflow and included four different patient care information systems.

METHODS

Setting

The adult ED at Vanderbilt University in Nashville, Tennessee is an urban, academic, level 1 trauma center with 41 beds. The ED staff includes 37 attending physicians, 34 resident

physicians, and 93 full-time nurses who provide care for more than 55,000 patient visits annually. The study was approved by the Institutional Review Board.

Study Design

We performed a prospective interventional study of a team-oriented, computerized reminder system designed to increase pneumococcal vaccination rates among elderly in an adult ED. The reminder was evaluated over a one-year study period from January 31, 2006 to January 31, 2007.

Participants

During ED triage all patients aged 65 years and older and seeking care in the ED were eligible and screened for inclusion. We excluded patients with life-threatening conditions defined as patients who were assigned the most severe acuity based on the 5-level Emergency Severity Index^{24, 25}; patients without physician-entered orders in the computerized provider order entry system; and patients without computerized triage documentation, such as patients who left without being seen or were referred to another clinic prior to the triage process. All visits from patients seeking care in the ED more than once during the study period were eligible, as each visit provides an opportunity to offer vaccination, and it is conceivable that the patient's clinical condition and acuity may influence the likelihood of a patient agreeing to receive a preventive care measure during an ED visit. The baseline pneumococcal vaccination rate was determined by patient reporting, i.e., the number of ED patients that were already vaccinated at the time of their ED encounter

All consenting attending and resident physicians providing care in the ED were eligible for inclusion in the study, including resident physicians from other departments rotating through the ED. The investigators provided eligible emergency medicine physicians information about the study during faculty and resident meetings, and rotating physicians during monthly orientation sessions. Only consenting physicians identified in the information system through the login credentials received the intervention. Among the 144 physicians who consented to participate during the course of the study, 75 were ED resident or attending physicians. The ED nurses were informed about the study at staff meetings.

Intervention

Prior to the study the adult ED did not have a pneumococcal vaccination policy and had not implemented systematic approaches to provide eligible patients with the vaccine. The intervention integrated the clinical workflow between the triage nurse, physician, and ED bedside nurse. The process of pneumococcal vaccination involves multiple ED team members which are responsible for different aspects of patient care. The computer-based pneumococcal reminder system included four different information systems (Figure 1): the electronic medical record^{26, 27}, the computerized triage application²⁸, the computerized provider order entry system²⁹, and the order tracking application. The four information system components are part of a homegrown ED information system infrastructure that integrates hospital-wide information systems (electronic medical record and computerized provider order entry) with ED specific systems (computerized triage and order tracking application)³⁰.

The institution's longitudinal electronic medical record includes a patient problem list consisting of semi-structured and free text sections for current and past medical history, medications, major procedures, and preventive care measures. The free-text preventive care section includes information about completed screening exams and the patient's current vaccination status.

The computerized triage application captures patient data in mostly coded format. To support the triaging process the application embeds sections of the patient problem list at appropriate places. The triage nurse completes an initial assessment of the patient's vaccination status while having access to the preventive care section of the patient's problem list. To document pneumococcal vaccination status, the nurse documents whether and when the patient received the pneumococcal vaccine, reconciling information from the electronic medical record, the patient, and, if appropriate, the individuals accompanying the patient. For eligible patients, assessing the pneumococcal vaccination status is mandatory. After completing the triage documentation, a summary page reminds the nurse for recommended clinical tasks that are a result of the triage assessment. If a patient meets the Centers for Disease Control and Prevention (CDC) age guidelines for pneumococcal 23-valent polysaccharide vaccination³¹, the triage summary page displays a reminder prompting the nurse to inform the patient about the recommended vaccination. After the opportunity to provide educational information, the nurse inquires whether the patient would like to receive the vaccine during the ED visit. If the patient declines, the system captures the refusal reason from a pre-populated list; otherwise the triage application notifies the computerized provider order entry system about the patient's eligibility and willingness to obtain the vaccine during the current ED visit.

The computerized provider entry system captures the ED patients' orders. The system prompts participating physicians to order the vaccine at the end of a physician's first ordering session. We chose to display the vaccination reminder during the first ordering session in case the system was used only once during an ED encounter. The timing at the end of the first session was chosen to lessen interference with orders that were related to the patient's primary reason for the ED visit. The reminder (Figure 2) provides information that the patient may be eligible, had agreed to receive the pneumococcal vaccine, and displayed the guideline criteria from the CDC. With one mouse click the physician was able to order the vaccine or to document the reason for not ordering it at the present time. An additional field captured voluntary, free text information associated with not ordering the vaccine. Order status and vaccination status perpetuate for hospital admitted patients

The ED order tracking system lists all orders from the computerized provider entry system and supports the nurse in managing and processing orders. Once a physician orders a pneumococcal vaccine the order tracking system captures vaccine administration information, which is then added to the health maintenance section in the electronic medical record. If a patient refuses the vaccine at the time of administration, the nurse can document the refusal in the system.

Data collection

Study data were obtained from the four information systems, the ED patient tracking system, and the billing database. The triage system provided data about patient age, gender, visit date and time, chief complaint, acuity level, and primary care physician information and pneumococcal vaccine status information, including prior vaccination, and the number of years since receiving the vaccination, which was used to determine guideline eligibility. If patients were eligible, the system captured a patient's interest in receiving the vaccination during the ED visit and a refusal reason if the patient declined.

The billing system provided information about race (white or other), religion (Christian, non-Christian, or none), language (English or other), and insurance information (Medicare or other). Average patient income information was estimated by zip code. The computerized provider order entry system captured information about the physician reminder, including date and time of a placed order or a refusal reason if the provider declined the order. The administration of the vaccination was determined from the ED order tracking system and

chart review, if necessary. To account for varying levels of ED workload which may influence the ED staff's willingness and ability to offer preventive care measures, we obtained the waiting room count, the average wait time, the occupancy rate, the average length of stay, the number of boarding patients, and the average ED acuity from the patient tracking system at the time of patient registration.

Outcome Measures

The primary outcome measure was the pneumococcal vaccine administration rate during the ED encounter. The secondary outcome measures included patient and physician refusal reasons.

Statistical Analysis

The statistical analysis concentrated on the association between the vaccination rate and ED workload variables including length of stay in the waiting room, the length of stay for boarding patients, and the occupancy of the ED. Multivariate logistic regression analysis was used to estimate the odds ratios (OR) and their 95% confidence intervals (CIs), representing the overall relative risks of ED workload related variables associated with vaccination rate, and to adjust for potential confounding variables including gender, age, income, and race. In addition, rates of events including patients' willingness in receiving the vaccine, presence of a physician prompt, order placement, and administration of the vaccination were calculated with the respective 95% confidence intervals. Descriptive statistics were computed overall and separately for patients who received vaccination and those who did not. All tests of significance were based on two-sided probabilities, at p -values < 0.05 . Statistical analyses were performed using R software (version 2.7.2).

RESULTS

Among 54,967 ED encounters 3,371 patients 65 years and older accounted for 4,927 (8.9%) visits. Among the eligible elderly patients 1,309 (38.8%) were up-to-date with vaccination, while 2,062 met eligibility criteria to receive the vaccine. Patient demographics are shown in table 1 and Figure 3 summarizes the patient flow.

During triage 1,441 (69.9%) patients refused vaccination and 621 (30.1%) were interested in receiving the vaccination during the ED visit. The most frequent patient refusal reasons at triage included "Patient prefers to receive the vaccination from his/her primary care physician" (35.7%), "Patient believes pneumococcal vaccination is not necessary" (16.7%), "Patient is afraid of side effects" (3.1%), "Patient believes pneumococcal vaccination causes pneumonia" (2.1%), "Patient had previous bad experience with vaccination" (1.2%), "Patient believes pneumococcal vaccination is not effective" (0.6%), and "Patient is afraid that vaccination is not covered by insurance" (0.5%). Other refusal reasons documented in the free text box included: patient has received the vaccination (8.2%), patient is unable to answer questions, language barriers, and the patient does not want one. Twenty-three patients refused the vaccination after it was ordered with reasons recorded including prior vaccination and no longer interested in receiving the vaccine.

Overall 222 patients (10.8%) received the pneumococcal vaccine during an ED visit and 111 (50%) patients received it during their first ED encounter. Vaccination administration was verified by chart review. The median number of visits needed for patients to receive a pneumococcal vaccination was 1.5.

Ninety-seven physicians were consented to participate in the study and no physicians withdrew from the study. Sixty-five physicians were prompted to order pneumococcal vaccinations. Physicians received prompts for 428 patients, 57% of consenting patients, and

placed 245 vaccination orders. The orders resulted in 222 administered vaccinations. The physicians received a median of 5 (range: 1 to 27) prompts each and placed a median of 2 (range: 0 to 17) orders. Physicians placed 19 spontaneous orders, i.e., vaccination orders that were placed without a prompt from the computerized order entry system. The system captured 192 refusals with 202 reasons given, as more than one reason was possible for a declined order. The most common physician refusal reasons were “I am unable to verify eligibility for immunization” (30%), “The patient has already received the vaccination” (15.6%), “There is not enough time” (14.6%), “The ED is not the place for primary care” (10.9%), “There are not enough personnel” (6.8%), “There is no structured protocol for vaccination in the ED” (1.6%), “I have concerns about adverse reactions” (4.2%), and “I am concerned about the cost of the vaccination” (1.0%). Other refusal reasons typed into the free text box included: caretaker refuses, not the primary concern, patient is critically ill, and unable to access medical history.

In the multivariate logistic regression analysis vaccination was associated younger age, Caucasian race, and longer ED boarding times (Table 3). Gender, acuity, income, patient type, admission status, and whether the patient had a primary care physician were not significant predictors for increasing vaccination rates. Longer boarding time variables that were used as markers for the level of the ED workload (ED occupancy, average total length of stay for boarding patients, length of stay in the waiting room, the number of boarding patients, and the number of patients in the waiting room) were not significant predictors for increasing vaccination rates.

COMMENT

The implementation of the computerized reminder system in the adult ED demonstrated a 10.8% increased pneumococcal vaccination rate among elderly ED patients. Compared to other pneumococcal vaccination initiatives that vaccinated 58% and 84% of eligible ED patients^{19, 21}, we consider the improvement moderate. However, these studies screened a convenience sample of ED patients, as opposed to the entire ED population, during a relatively short time period. In addition, these studies required a considerable number of additional staff that was dedicated to the initiative, thus had a low level of sustainability. Our method differed as the information technology supported infrastructure facilitated a workflow-embedded and team-oriented approach as well as a more sustainable infrastructure that did not depend on additional resources in the ED.

The overall vaccination declination rate was high when compared with other non-ED studies. Many patients refused vaccination when asked during triage, suggesting an increased need for patient education. Although the nurses were able to check the medical record for vaccination status, patient reporting was taken as the most important source of information for determining eligibility. While most of the patients (79%) reported having a primary care physician, only 50% reported being up-to-date with pneumococcal vaccination. Patients recalling accurately the status and date of their vaccinations is a further limitation of assessing eligibility. This may be addressed through vaccination registries or health information exchange systems that connect primary care physician offices with healthcare institution. To assess accurately vaccination status and eligibility criteria, other studies have involved dedicated healthcare workers that have more dedicated time to focus on vaccination status and eligibility criteria, and have achieved higher rates. This approach, however, is not integrated with the normal ED patient care process, causes additional resources and costs, and is more difficult to implement on an ongoing basis.

Triage may not be the ideal time and location for screening patients for vaccinations. Asking patients about vaccination status when they present in an emergency condition, often

combined with pain, is not an ideal situation for the patient or the care providers in the ED. As the ED gets busy the triage nurses are often focused on patient throughput and, unfortunately, may spend less time on non-emergency related aspects of preventive health care. Vaccination screening may be more suitable at the patient's bedside when the most relevant aspects of the patient's reason to seek care in the ED are addressed and the bedside nurse may have more time. Bedside screening, however, may also require a nurse reminder and may not occur until later during a patient's ED visit when a physician has already completed all necessary interactions with the order entry system. In this case the physician may not receive the reminder at the time of the first order session or may have to initiate an additional order entry session solely for the purpose of ordering the vaccination. Alternatively, a standing nurse order for pneumococcal vaccination may delegate the preventive care measure to the nursing staff and would not require physician interaction for the large majority of patients.

A possible reason for physician refusal of ordering vaccination could be the design of the prompt in the order entry system or the design of the workflow. While the design of the physician prompt included additional information, it was designed to emulate other reminders in the order-entry system that displayed additional and supporting information without further user interaction. The order vaccination option was pre-selected to make ordering the vaccine as easy and quick as possible. An alternative reminder workflow would prompt first the physician in the order entry system, at which time the physician may not know the patient's vaccination status.

This would require asking the patient or querying the electronic medical record, and then return to the order entry system to complete the session or initiate an additional session. It remains unclear whether any of the alternative workflows would result in a higher vaccination rate.

As our ED did not have a pneumococcal vaccination policy, the current system represents a feasibility study for the integrated approach. Prior to initiating the implementation of the reminder system, the beliefs and attitudes of the nurses and physicians towards vaccination in an emergency care setting were overall positive³².

The informatics approach focused on strong clinical workflow integration by taking advantage of the various clinical information system components. The reminder system utilized the electronic medical record to retrieve vaccination status, the computerized triage application to support the determination of a patient's eligibility criteria, the provider order entry system to remind physicians to order the vaccine for eligible and consenting patients, the order tracking system to notify the nurses about the vaccine order, and finally the longitudinal electronic medical record which captured the vaccination update documentation and makes the information available for subsequent healthcare episodes including repeat visits in the ED.

For patients younger than 65 years old an automated method to determine eligibility for would ideally have coded co-morbidities electronically available (e.g., abnormal innate immune response or functional or anatomic asplenia). The problem list in our EMR is currently semi-structured making the integration of past medical history information more challenging. Asking the triage nurse to collect this information would not fit easily into the current workflow and investigating a computerized approach may represent a next step. A possible computerized solution would involve parsing of free-text terms on the problem list or the application of natural language processing methods. Furthermore, the date of prior pneumococcal vaccinations is needed in the electronic medical record to evaluate the guideline recommendations. We have developed an approach to identify pneumococcal

vaccination from the health maintenance section and free text reports³³; however, determining the date of administration remained a challenge. Reminder systems have been effective in the inpatient setting with similar CPOE adoption issues from providers²². One of the system's limitations is that it only targets an elderly population. Previous work and early experiences from our ED suggest that this patient group includes about 49% of eligible patients³⁴. For two years (2004–2005) prior to the study period there were only three spontaneous vaccination orders for ED patients out of 399 inpatient vaccination orders in the hospital.

The informatics approach evaluated in this study may be expanded to other vaccinations and preventive care procedures, as additional data captured by busy ED clinicians were limited and relevant data were presented at the time of decision making. Studies of vaccine delivery methods suggest that standing orders are the best way to improve vaccination coverage in an office, hospital, or long term care settings³⁵, although clinician prompts have also been effective at increasing vaccination rates in both the inpatient and outpatient settings^{36, 22, 37}. We believe the approach can be successfully applied at other institutions to improve preventive care practices, given that an appropriate information system infrastructure is available.

In summary, we believe this to be the first study targeting pneumococcal vaccination in the ED using fully computerized tools. Our system may be scalable to other vaccinations and preventive care procedures.

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Figure 1. Team-oriented workflow in the emergency department. The outer circle contains the ED information systems. Inside the circle shows the patient and provider interactions with each other and the system. CPOE: Computerized Provider Order Entry, EMR: Electronic Medical Record.

Pneumococcal Vaccination Reminder	
<p>Your patient may be eligible for pneumococcal vaccination. Please verify eligibility.</p> <p>Would you like to order the vaccine?</p> <p>☒ Yes, order Pneumococcal vaccination (Pneumovax-23) (PNEUMOCOCCAL VACCINE INJ 0.5mL IM x1)</p> <p>☐ No, do NOT order vaccine</p> <p>Please provide a reason for not ordering:</p> <p>☐ I have concerns about adverse reactions.</p> <p>☐ The ED is not the place for primary care.</p> <p>☐ I am unable to verify eligibility for immunization.</p> <p>☐ The patient has already received the vaccination.</p> <p>☐ There is not enough time.</p> <p>☐ There are not enough personnel.</p> <p>☐ I am concerned about the cost of the vaccination.</p> <p>☐ There is no structured protocol for vaccination in the ED.</p> <p>Other: <input type="text"/></p>	<p>Absolute contraindications for vaccination:</p> <ul style="list-style-type: none"> • Previous allergic reaction to any pneumococcal vaccine component. • Supratherapeutic INR. • Patient is in first trimester of pregnancy. <p>CDC Guidelines:</p> <ul style="list-style-type: none"> • Patient is ≥ 65 years of age • Patient has functional or anatomic asplenia. • Patient lives in an environment in which the risk for disease is high. <ul style="list-style-type: none"> ◦ e.g. Nursing home residents, American Indians, Alaskan Natives • Patient is immunocompromised with a chronic illness: <ul style="list-style-type: none"> ◦ e.g. cardiac disease, COPD, diabetes, chronic liver disease, sickle cell disease, etc. • Patient aged 2-64 years with a chronic illness: <ul style="list-style-type: none"> ◦ e.g. cardiac disease, COPD, diabetes, chronic liver disease, sickle cell disease, etc. <p>At the discretion of the Physician:</p> <ul style="list-style-type: none"> • Patient has a lung infection. • Patient has an acute illness (fever/diarrhea/vomiting). • Patient has cold or flu-like symptoms. • Patient will be admitted to the hospital. • Anticoagulation therapy (Coumadin).
<p align="center">Submit and Exit</p>	

Figure 2.
Physician prompt for pneumococcal vaccination in the computerized provider order entry system. The left side contains the vaccination order. The right side contains the CDC guidelines for patient eligibility.

Figure 3.

Patient flow diagram for emergency department visits.

* Some physician responses were lost with an update to the computerized provider order entry system.

Table 1

Demographic characteristics for ED Patients >65 years (n=3371) evaluated during study period. ESI: Emergency Severity Index

Female, (%)	1940	(58)
Age, mean±SD (LQ ¹ ,UQ ²)	76±7.6	(69,81)
Acuity (ESI), (%)		
2	2004	(59)
3	1187	(35)
4	180	(5)
Ethnicity, (%)		
White	2729	(81)
Other	642	(19)
Income, mean±SD (LQ,UQ)	43900±17417	(32120, 51790)
ED Visits, mean±SD (LQ,UQ)	1.46±1.28	(1, 1)
Primary care physician, (%)	2533	(75)
Hospital Admission, (%)	1894	(56)
Patient Type, (%)		
Emergency Department	1627	(48)
Inpatient/Observation	1744	(52)
Religion, (%)		
Christian	2255	(67)
Non-Christian	523	(16)
None	580	(17)
N/A	13	(0.4)
English Language, (%)	3318	(98)
Insurance, (%)		
Medicare	2987	(89)
Other	384	(11)

¹ Lower Quartile,

² Upper Quartile,

Table 2

Characteristics of Patients Stratified by Pneumococcal Vaccination Status

Characteristic	Not Vaccinated (n=3149)	Vaccinated (n=222)	P Value
Gender, Female (%)	1819 (58)	121 (55)	0.34
Age, years	76 (7.6)	74 (7.4)	0.002
Acuity (%)			
2	1867 (59)	137 (62)	
3	1114 (35)	73 (33)	
4	168 (5)	12 (5)	0.75
Race (%)			
White	2594 (82)	135 (61)	
Other	555 (18)	87 (39)	<0.001
Patient type (%)			
Emergency Room	1519 (48)	108 (49)	
Inpatient/Observation	1630 (52)	114 (51)	0.91
Primary care physician (%)			
Yes	2368 (75)	165 (74)	0.77
Income	44146 (17474)	37340 40427 (16229)	0.001
ED Occupancy at time of registration (%)	82 (16.8)	82 (19.8)	0.71

Table 3

Multivariate Analysis: Predictors for ED patients that received the pneumococcal vaccination (n = 222)

Variable	Odds Ratio (95% CI)	P value
Female	0.86 (0.65–1.15)	0.32
Patient type	1.10 (0.82–1.48)	0.52
Age, years	0.97 (0.95–0.99)	0.005
Income (in thousand dollars)	1.00 (1.00–1.00)	0.43
Race	0.33 (0.24–0.45)	<0.001
Acuity	1.02 (0.74–1.40)	0.41
Primary Care Physician	0.90 (0.70–1.16)	0.92
WR LOS	1.02 (1.00–1.05)	0.07
Boarding LOS	1.04 (1.01–1.06)	0.003
Occupancy of ED	0.99 (0.99–1.00)	0.22

WR: Waiting room; LOS: Length of stay, ED: Emergency department