To Batch or Not to Batch: Sequential vs. Batched Testing Strategies in the ED

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This paper focuses on analyzing sequential versus batched testing strategies in an emergency department (ED) at Mayo Clinic Arizona, with respect to their associations impacts on patient length of stay, hospital readmission, and healthcare resource utilization. A theoretical model was developed and tested to identify patient and hospital features that may influence the decision to batch or sequentially order tests, such as patient complexity, physician experience, occupancy level and complexity. Finally, we performed retrospective analysis of ED operational data to investigate the impact of batching on our key outcomes. The overall result was that batch ordering tests was associated with greater patient length of stay and resource utilization, even when we control for variation in patient complexity, physician experience, and hospital occupancy.

Key words: Emergency Department, Operational Effeciency, Diagnostic Testing

1. Introduction

Healthcare delivery, particularly in the emergency department (ED), is a delicate balance that involves ensuring optimal patient outcomes while optimizing resource utilization. Achieving these twin goals requires timely and accurate diagnosis, which in turn enables prompt and appropriate treatment, consequently improving patient prognosis and reducing the likelihood of adverse events. Furthermore, efficient patient discharge from the ED can help alleviate overcrowding, a severe issue with potential consequences including higher complication rates and increased mortality Bernstein et al. (2009).

One important factor that can impact the speed and effectiveness of diagnosis in the ED is the availability and performance of diagnostic tests Balogh et al. (2015). A variety of diagnostic tests are used in the ED, including laboratory tests, imaging studies, and specialized tests such

as electrocardiograms (ECGs) and point-of-care (POC) testing. These tests can provide valuable information about a patient's condition and help to guide treatment decisions.

A critical question in this context pertains to whether physicians in the ED should batch order diagnostic tests or order them sequentially. This decision essentially represents a tradeoff between reducing patient length of stay and risk of over-testing. Over-testing, or performing unnecessary tests, can lead to increased costs, unnecessary patient anxiety, and potential harm from follow-up of false-positive results Koch et al. (2018). Conversely, keeping a patient for an extended time to perform all possible tests could lead to ED overcrowding, an issue associated with severe consequences, as mentioned earlier. Instead, what is needed is a reasonable balance between the number of diagnostic tests performed and the total time the patient is kept in the ED before either being admitted or discharged. Several studies have demonstrated that optimizing the ED patient flow process can result in significant improvements Saghafian et al. (2015), however, research surrounding test ordering strategies to improve the patient flow processes remains limited.

In this paper, we use data from over 41,000 patient visits to the ED that occur during our study period to quantify the benefits and consequences of batching versus sequentially ordering diagnostic tests on patient length of stay, re-admission, and resource utilization. Our empirical strategy exploits random assignment of patients to ED physicians who differ in their propensity to batch-order diagnostic tests. When patients arrive at the ED, they are assigned to a physician based on availability, with no discretion on either side. Thus, patients who arrive at the ED at similar times are randomly assigned to physicians who vary in their willingness to batch order diagnostic tests. We measure physician tendency to batch using a leave-out, residualized measure based on all other patients the physician has seen in the ED in the study period. The tendency measure strongly predicts the ED test batch outcome but is uncorrelated with patient and ED visit characteristics.

We start by evaluating the reduced-form effects of ED provider batch ordering tendency on downstream patient outcomes and turnaround time. We find that practice variation as captured by physician batch-ordering tendency has large and significant consequences. Being treated by a provider in the top decile of the leniency distribution, compared to being treated by someone in the bottom decile [INSERT RESULTS].

Because of the institutional features of the ED, our research design closely approximates an RCT that assigns patients to batch-ordering or sequential-ordering arm. In the ED, patients have no discretion over choosing providers, and in our specific ED, physicians have discretion over choosing patients, alleviating major selection issues present in other health care settings. Furthermore, physicians exhibit wide variation in practice behavior in batch ordering, even within the same hospital, while following the same guidelines. Finally, patient-physician interactions in the ED are

typically well documented, short, and one-off, constraining physician decision-making to a more limited, better-observed choice set than present in settings such as specialty or primary care.

In sum, exploiting practice variation in ED settings shuts down other (but not all) potential channels besides test batching that are present in other settings, determine length of stay, and impact patient outcomes. This approach allows us to move closer to identifying the causal impact of batch-ordering diagnostic tests on patient outcomes and hospital effeciency. It is important to note that this paper studies the impact of an batch-ordering through a batching decision requiring clinical judgment (within practice norms) rather than through specific hospital policies, differences in adherence to clinical practice guidelines, or substandard care.

The remainder of this paper is structured as follows. The next section describes the data source and outlines our baseline sample. The empirical strategy and its accompanying identifying assumptions are laid out in Section II. Section III presents the results. Section IV draws implications for batch-ordering policies. The last section concludes.

2. Data and Definitions

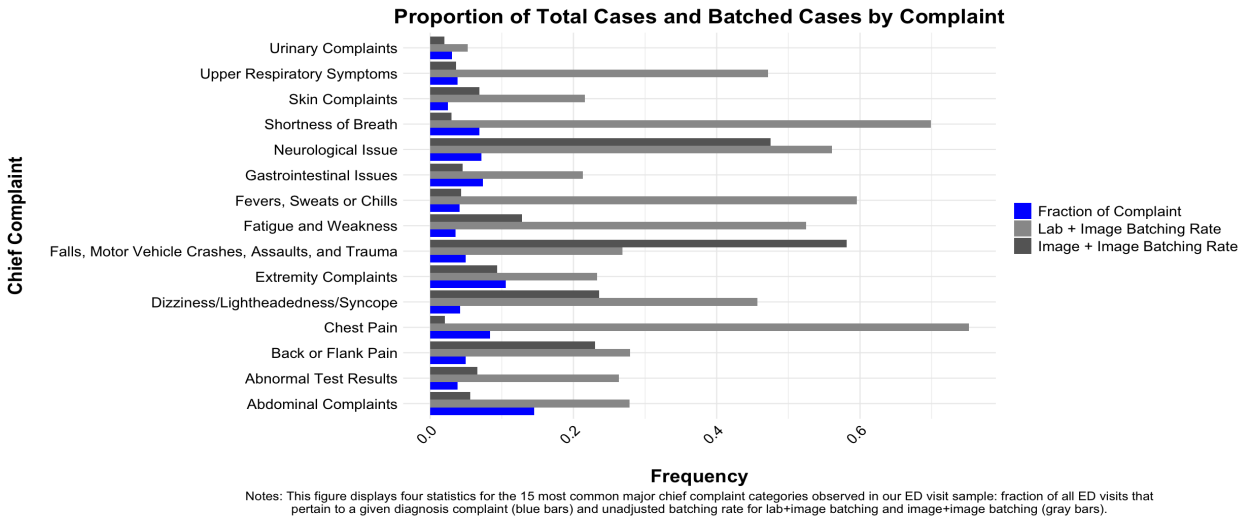
Our analytical lens is focused on the Emergency Department at the Mayo Clinic of Arizona, a distinguished tertiary care establishment. During our study's timeframe, the ED recorded an annual visitation of approximately 41,000 patients. The department is singularly staffed by board-eligible or board-certified emergency physicians, abstaining from the services of nurse practitioners or physician assistants. A notable observation was that residents in rotation oversaw a low fraction, roughly 10%, of the patient volume. Comprehensive patient data, encompassing demographics, chief complaints, vital signs, emergency severity, length of stay, and resource utilization metrics, were meticulously logged during the study period.

2.1. Sample Construction

We identified three distinct forms of test batching:

- Lab/Image Batch: The first test ordered for a patient was either an imaging or lab test (CT scan, X-ray, Ultrasound, Lab), followed by an additional imaging or lab test order within 5 minutes.
- Image/Image Batch: The first test ordered for a patient was an imaging test (CT scan, X-ray, Ultrasound), followed by an additional imaging test order within 5 minutes.
- Any Batch: This refers to instances where either a Lab/Image Batch or an Image/Image Batch occurred.

We conducted a sensitivity analysis for this definition, documented in Appendix 2. Table 1 highlights the considerable variation in patient complexity between those who had their tests batch ordered versus those where tests were ordered sequentially.



Notes: This figure displays four statistics for the 15 most common major chief complaint categories observed in our ED visit sample: fraction of all ED visits that pertain to a given diagnosis complaint (blue bars) and unadjusted batching rate for lab+image batching and image+image batching (gray bars).

Figure 1 Frequency of Sample Cases and Batches

2.2. Statistics

Table 1 provides a comprehensive breakdown of the patient encounters involving diagnostic tests ordered either individually (Sequential) or as part of a group (Batch) during an ED encounter from our baseline sample. Around 43% of patient encounters involved diagnostic tests ordered as part of a batch, the majority of which (60%) included two tests.

Differences were noted between the two cohorts. Patients who had batched tests ordered tended to have a longer ED length of stay, a lower Emergency Severity Index (ESI), and were generally older than those who had their tests ordered individually. Patients in the batch order group were also more likely to present with symptoms at triage, including tachycardia, tachypnea, fever, and hypotension. A deeper dive into the ESI data reveals a higher proportion of patients with more urgent conditions (ESI 1 and 2) in the batched group than in the sequential group. This finding might be indicative of the complexity and severity of the conditions of patients who necessitate batch testing.

Age distributions between the two groups demonstrate a greater proportion of patients aged 65 and above in the batch group, suggesting that older patients are more likely to have multiple tests ordered at once, possibly due to the presence of multiple comorbidities. The batched group showed a longer average ED length of stay compared to the sequential group. This extended stay may be reflective of the additional time required to conduct and evaluate the results of multiple tests. Symptoms presentation at triage also differed between the two groups, with the batched group being more likely to present with tachypnea, fever, and hypotension. However, tachycardia was found to be similar across both groups.

Table 1 Summary Statistics for Sequential vs. Batched Test Groups

Variable	Overall Visits, N = 41,197[1]	Sequential Arm, N = 23,4331	Batching Arm, N = 17,7641	p-value[2]
ESI				<0.001
1	474 (1.2%)	130 (0.6%)	344 (1.9%)	
2	13,911 (34%)	6,502 (28%)	7,409 (42%)	
3	23,655 (57%)	14,350 (61%)	9,305 (52%)	
4	3,123 (7.6%)	2,422 (10%)	701 (3.9%)	
5	34 (<0.1%)	29 (0.1%)	5 (<0.1%)	
Age				<0.001
<20	790 (1.9%)	605 (2.6%)	185 (1.0%)	
20-45	9,412 (23%)	6,242 (27%)	3,170 (18%)	
45-65	12,826 (31%)	7,393 (32%)	5,433 (31%)	
65+	18,169 (44%)	9,193 (39%)	8,976 (51%)	
ED LOS				<0.001
Mean (SD)	270 (382)	258 (177)	286 (545)	
72hr Return	1,482 (3.6%)	957 (4.1%)	525 (3.0%)	<0.001
Number of Tests				<0.001
1	12,961 (31%)	11,937 (51%)	1,024 (5.8%)	
2	19,112 (46%)	8,457 (36%)	10,655 (60%)	
3	7,688 (19%)	2,581 (11%)	5,107 (29%)	
4	1,342 (3.3%)	432 (1.8%)	910 (5.1%)	
5	94 (0.2%)	26 (0.1%)	68 (0.4%)	
Disposition				<0.001
Discharge	25,302 (61%)	15,922 (68%)	9,380 (53%)	
Admit	9,097 (22%)	4,209 (18%)	4,888 (28%)	
Other	6,798 (17%)	3,302 (14%)	3,496 (20%)	
Tachycardic	8,115 (20%)	4,562 (19%)	3,553 (20%)	0.18
Tachypneic	3,822 (9.3%)	1,669 (7.1%)	2,153 (12%)	<0.001
Febrile	969 (2.4%)	353 (1.5%)	616 (3.5%)	<0.001
Hypotensive	651 (1.6%)	305 (1.3%)	346 (1.9%)	<0.001
Gender				<0.001
Female	22,105 (54%)	12,986 (55%)	9,119 (51%)	
Male	19,092 (46%)	10,447 (45%)	8,645 (49%)	
Race				<0.001
White	36,554 (89%)	20,665 (88%)	15,889 (89%)	
Black	1,682 (4.1%)	974 (4.2%)	708 (4.0%)	
Asian	1,217 (3.0%)	710 (3.0%)	507 (2.9%)	
Other	737 (1.8%)	449 (1.9%)	288 (1.6%)	
Native	538 (1.3%)	340 (1.5%)	198 (1.1%)	
Unknown	469 (1.1%)	295 (1.3%)	174 (1.0%)	

[1] n (%)
[2] Pearson's Chi-squared test; Welch Two Sample t-test

2.3. Institutional Details on Patient-Physician Assignment

Contrary to most healthcare settings where patients exhibit choice, they are predominantly passive in their physician assignment in the ED. In most EDs, however, physicians have discretion in picking their patients. In contrast, patients arriving at the Mayo Clinic ED are randomly assigned to physicians via a rotational patient assignment algorithm (Traub et al., 2016), which removes potential selection bias concerns for our analyses. In essence, barring arrival time and shift-level variation, the physician-to-patient matching can be deemed random. Exhibit 2 displays that patient encounters (regarding chief complaints and emergency severity) are equitably distributed across physicians within our study's cohort.

3. Empirical Strategy

Our study employs the "judges design", a quasi-random assignment strategy widely used in literature to investigate causal effects. Typically, this design exploits variations in sentencing leniency among judges working in the same court. We adopt a similar approach by examining batching variations across physicians working in the same emergency department. This method enables us to identify the causal impact of being assigned to different types of physicians with differing batch-ordering tendencies.

Table 2 Wald Test Results

Chief Complaints	F-Statistic	$Pr(>F)$
Abdominal Complaints	1.37	0.106
Back or Flank Pain	1.00	0.451
Chest Pain	0.98	0.476
Extremity Complaints	0.97	0.495
Falls, Motor Vehicle Crashes, Assaults, and Trauma	0.73	0.812
Gastrointestinal Issues	0.98	0.480
Neurological Issue	0.75	0.793
Shortness of Breath	1.23	0.199
Skin Complaints	1.05	0.388
Upper Respiratory Symptoms	1.21	0.218
Emergency Severity	**F-Statistic**	$Pr(>F)$
ESI 1 or 2	1.09	0.346
ESI 3, 4, or 5	1.24	0.196

Table [blank] reports the results of a Wald test which was conducted to assess the balance of chief complaints across providers in our dataset. A balanced distribution implies that complaints and severity are evenly distributed across providers, which we expect to be the case due to randomization. The Wald F-statistic and p-value are reported. Robust standard errors (type HC1) were used to account for potential heteroscedasticity in the data.

To measure physician batch tendency, we use the physician's residualized leave-out average batch rate. This measure is derived from two steps following the approaches taken by Doyle et al. (2015), Dobbie et al. (2018), and Eichmeyer and Zhang (2022). First, we obtain residuals from a regression model, which includes all ED encounters in our sample period.

$$Batched_{i,t} = \alpha_0 + \alpha_{ym} + \alpha_{dt} + \varepsilon_{i,t} \tag{1}$$

Where $Batched_{i,t}$ is a dummy variable equal to one if patient i had their diagnostic tests batched on encounter that took place on data t. Fixed effects include year-month fixed effects, α_{ym}, to control for time and seasonal variation in batching, such as hospital-specific policies (e.g. initiatives to eliminate excess testing) or seasonality in ED visits. We also control for "shift-level" variations that include both physician scheduling and patient arrival with day of week-time of day fixed effects, α_{dt}. As stated earlier, these controls are what is required for our quasi-random assignment assumption. Under the assumption that we have captured the observables under which quasi-random assignment occurs in the ED, the unexplained variation– the physician's contribution– resides in the error term, $\varepsilon_{i,t}$.

In step two, the leniency measure for patient i seen by physician j is computed as the average residual across all other patients seen by the physician that year:

$$Tendency_{i,j}^{phys} = \frac{1}{N_{-i,j}} \sum_{i' \in \{J \setminus i\}} \hat{e}_{i',k} \tag{2}$$

where $\hat{e}_{i',k} = \hat{Batch}_{i',k} - Batch_{i',k}$ is the residual from equation (1); J is the set of all ED encounters treated by physician j; and $N_{-i,j} = |\{J \backslash i\}|$, the number of cases that physician has seen that year, excluding patient i. This leave-out mean eliminates the mechanical bias that stems from patient i's own case entering into the instrument. The measure is interpreted as the average (leave-out) batch rate of patient i's physician, relative to other physicians in that hospital-year-month, hospital-day of week-time of day.

We document that the Mayo Clinic ED physicians exhibit wide, systematic variation in their propensity to batch order diagnostic tests. Figure 2 graphs the histogram of the leniency measure along the x-axis and the left y-axis. A local-linear regression of the fitted probability of batched ordering on tendency after residualizing is overlaid and displayed on the right y-axis. Table 2 presents the same "first stage" in a regression table: being assigned to a 10 pp more lenient physician is associated with a 17 pp increase in the likelihood of being prescribed an opioid in the ED. The F-statistic is 25 when all controls and fixed effects are included. The coefficient is greater than one because all emergency visits are used to construct the leniency instrument, while the first stage is calculated using the baseline sample only, which excludes the rarely prescribed diagnoses.

To estimate the reduced-form effects of being treated by a batch-preferring physician, we estimate the following equation:

$$Y_i = \mu_0 + \mu_1 Tendency_{i,j}^{phys} + \gamma X_i + \nu_i \tag{3}$$

This reduced form will allow us to check that our instrument is a strong instrument. To study the effects of test batching in the ED on an outcome Y_i, we estimate the following 2SLS equations using our baseline sample:

$$Y_i = \beta_0 + \beta_1 Batched_i + \theta X_i + \varepsilon_i \tag{4}$$

$$Batched_i = \delta_0 + \delta_1 Tendency_{i,j}^{phys} + \delta_2 X_i + \nu_i \tag{5}$$

Where Y_i represents our main outcomes of interest: length of stay, 72 hour readmission, and resource utilization.

and X_i is the same as in the reduced-form approach. $Batched_i$ variable suffers from potential endogeneity concerns. For example, injury severity may be unobserved and correlated with need to run multiple tests, which in turn also affects length of stay. Hence, we instrument $Batched_i$ with the assigned physician j's underlying tendency to batch, $Tendency_{i,j}^{phys}$ We cluster robust standard errors at the physician level to account for the assignment process of patients to physicians.

Table 3 First Stage Regression Results

	Model 1	Model 2	Model 3
Lab + Image Batching Tendency	0.99***	1.02***	1.02***
	(0.01)	(0.01)	(0.01)
F statistic (proj model)	13206.68	6702.01	6655.86
F (proj model): p-value	< 0.001	< 0.001	< 0.001
Image + Image Batching Tendency	0.92***	0.94***	0.94***
	(0.02)	(0.04)	(0.04)
F statistic (proj model)	1645.35	577.97	577.09
F (proj model): p-value	< 0.001	< 0.001	< 0.001
Num. obs.	41197	41197	41197
Seasonality and shift fixed effects?	Yes	Yes	Yes
Chief Complaint?	No	Yes	Yes
Patient observables?	No	No	Yes

Notes: Estimates of the first stage for the baseline sample described in the text. Seasonality shift fixed effects include Year-Month and Hospital-Day of week-Hour of day fixed effects. Chief complaint comes from the cleaned complaint that the patient came in with at the initial encounter. Patient observables include sex dummy, race/ethnicity, and age bins. Column 3 corresponds to the baseline controls. Robust standard errors are clustered at the physician level.

$***p < 0.001$, $**p < 0.01$, $*p < 0.05$.

3.0.1. Identifying Assumptions The reduced-form approach delivers an unbiased estimate of the causal effect of being treated by a higher tendency to batch physician, if assignment of patients to ED physicians is random, conditional on seasonality, shift, and diagnosis ("conditional independence"). One can test for whether batch-likely physicians are routinely assigned patients with particular characteristics. Figure 4 shows evidence of balance on observables. The left panel is the output of a regression of Prescribed on observables including patient demographics, priority groups, and ED diagnoses. Unsurprisingly, many observables predict length of stay and 72 hour return. The right panel displays the coefficients from a regression of physician tendency instrument on the same set of observables. With so many coefficients, we fail to reject that the instrument violates conditional independence (the joint F-stat drops by two orders of magnitude, from 280 to 2.4). In fact, some of the variables that are significant in the second column go in the opposite direction of the decision to batch

The residualization in equation (1) controls for more controls than required to achieve quasi-random assignment; they are included for statistical precision in measuring physician tendency to batch. In Appendix Figure [XXX], residualizing for only seasonality and shift (left panel) and also

diagnosis (right panel) in equation (1). This lends support to our assumption that assignment in the ED is nearly random at the seasonality, shift level.

Our instrumental variable approach, which aims to recover the causal effect of having diagnostic tests batch ordered, relies on three additional assumptions: relevance, exclusion, and monotonicity. We reported a strong first stage (i.e., relevance) at the end of the previous Section. The exclusion restriction requires that the instrument must influence the outcome of interest only through its effect on test batching. This is perhaps our strongest assumption and is at its core, untestable. However, several features of the ED setting suggest that such violation may likely only have a small impact and may be less concerning than in other health care settings. First, unlike in primary care settings, where the patient and primary care provider have many repeat encounters, the scope of what the emergency physician can do to impact medium-term outcomes is limited and well-observed by the researcher. Second, any violation of the exclusion restriction needs to directly affect the specific outcome of interest. The channel by which ED physicians can influence length of stay relative outcomes is likely through testing and diagnosis. Nevertheless, we take this assumption seriously and perform a placebo check in Section IIIB as well as various robustness checks in Section IIIE.

3.1. Results

3.1.1. Reduced-Form Results In this section, we examine the causal effects of provider batching tendency. We first present the effects on our main outcomes of length of stay, 72hr readmission, and healthcare resource utilization (number of tests).

4. Conclusion

Appendix. General appendix

Table 4: Chief Complaints

Complaint Area	**Complaints**
Abdominal Complaints	Abdominal Cramping, Abdominal Distention, Dyspepsia, Abdominal Pain, Ascites, Hernia, Abdominal Aortic Aneurysm, Abdominal Injury, Pancreatitis, Umbilical Hernia
Abnormal Test Results	Abnormal Lab, Abnormal Potassium, Abnormal Calcium, ECG Changes, Abnormal ECG, Abnormal Test Result, Blood Infection, Acute Renal Failure, Hypocalcemia, Chronic Renal Failure, Pulmonary Embolism, Abnormal X-ray, Hypoglycemic Unawareness, Elevated Blood Pressure, Abnormal Sodium, Hyperglycemia, Hyponatremia, Platelet Disorders, Anemia, Hypoglycemia, Hypertension, Hypotension, Abnormal Chest Imaging, Abnormal Oximetry, Abnormal Stress Test, Blood Sugar Problem, Hypocalcemia, Hyponatremia
Allergic Reaction	Allergic Reaction, Anaphylaxis
Back or Flank Pain	Back Pain, Back Problem, Flank Pain, Sciatica, Back Injury, Disc Disorder
Breast Complaints	Breast Mass, Breast Pain, Breast Problem, Breast Discharge, Breast Cancer, Breast Discharge, Breast Inflammation
Cardiac Arrhythmias	Atrial Fibrillation, Atrial Flutter, Cardiac Valve Problem, Bradycardia, Irregular Heart Beat, Palpitations, POTS, Ventricular Tachycardia, Rapid Heart Rate, Heart Problem, Cardiac Arrest, Congestive Heart Failure, Circulatory Problem, Transient Ischemic Attack, Ventricular Tachycardia
Chest Pain	Chest Injury, Chest Pain, Chest Wall Pain, Angina, Collarbone Injury, Rib Injury, Heart Pain
Dizziness / Lightheadedness / Syncope	Dizziness, Near Syncope, Syncope, Vertigo, Spells, Hypotension, Paroxysmal Positional Vertigo, Paroxysmal Positional Vertig
Ear Complaints	Cerumen Impaction, Ear Drainage, Ear Fullness, Ear Laceration, Ear Problem, Earache, Hearing Problem, Tinnitus, Ear Injury, Hearing Loss, Nasal Trauma
Epistaxis	Epistaxis, Epistaxis (Nose Bleed), Nose Problem
Exposures, Bites, and Envenomations	Animal Bite, Body Fluid Exposure, Chemical Exposure, Poisoning, Exposure to STD, Insect Bite, Smoke Inhalation, Radiation, Snake Bite, Toxic Inhalation
Extremity Complaints	Ankle Injury, Ankle Pain, Arm Injury, Arm Pain, Cold Extremity, Arm Swelling, Arthritis, Elbow Injury, Elbow Pain, Pseudogout, Extremity Pain, Extremity Weakness, Finger Injury, Hip Injury, Extremity Weakness, Finger Injury, Finger Pain, Dislocation, Foot Infection, Foot Injury, Foot Numbness, Foot Pain, Foot Swelling, Foot Ulcer, Foot Wound Check, Hand Injury, Hand Pain
Eye Complaints	Blurred Vision, Decreased Visual Acuity, Diplopia, Detached Retina, Eye Drainage, Eye Exposure, Eye Pain, Eye Problem, Eye Swelling, Eye Trauma, Foreign Body Eye, Flashes / Light, Loss of Vision, Red Eye, Visual Field Change, Eyelid Problem, Itchy Eye, Eye Exam, Burning Eyes, Eye Twitching, Eyelid/brow Lift Evaluation, Strabismus, Glaucoma, Spots / Floaters
Falls, Motor Vehicle Crashes, Assaults, and Trauma	Assault Victim, Concussion, Facial Injury, Fall, Nasal Trauma, Head Injury, Head Laceration, Motor Vehicle Crash, Puncture Wound, Sexual Assault, Trauma, Domestic Violence, Gun Shot Wound, Work Related Injury, Motorcycle Crash, Injury, Bicycle Accident, Near Drowning, Lip Laceration
Fatigue and Weakness	Difficulty Walking, Fatigue, Gait Problem, Weakness-Generalized, Chronic Fatique, Weakness- Generalized
Fevers, Sweats or Chills	Chills, Diaphoresis, Fever, Night Sweats, Diaphoretic, Diapohresis, Hoarseness, Laryngitis
Foreign Body	Food Bolus, Foreign Body, Foreign Body in Ear, Foreign Body in Skin, Foreign Body in Vagina, Swallowed Foreign Body, Foreign Body in Nose, Foreign Body, FB eye, Foreign Body in Rectum

Gastrointestinal Issues	Anal Fissure, Black or Bloody Stool, Constipation, GERD, Anal Fistula, Diarrhea, Dysphagia, Fecal Impaction, Fistula Follow Up, GIbleeding, GI Problem, Hemorrhoids, Morning Sickness, Nausea, Ostomy Care, Rectal Bleeding, Rectal Pain, Vomiting, Vomiting Blood, Vomiting During Pregnancy, GI Bleeding, Fecal Incontinence, Bloated, Hematochezia, Urine Leakage, Heartburn, Rectal Discharge, Urolithiasis, Ulcerative Colitis, Irritable Bowel Syndrome, Rectal Prolapse, Fistula Evaluation, Rectal Problems, Perianal Abscess, Fisula Evaluation, Stoma Dysfunction
Genital Complaints	Groin Burn, Groin Pain, Groin Swelling, Inguinal Hernia, Menstrual Problem, Pelvic Pain, Penis Pain, Priapism, Testicle Pain, Menorrhagia, Vaginal Bleed, Vaginal Bleeding, Vaginal Itching, Bartholin's Cyst, Genital Warts, Groin Injury, Vaginal Bleeding-Pregnant, Vag Bleed Pregnant, Female Genital Issue, Penis Injury, Vaginal Discharge, Vaginal Pain, Erectile Dysfunction, Vaginal Prolapse, Urethral Stricture, Penile Discharge, Menorrhagia, Gynecologic Exam, Menstrual Problem, Vaginitis/Bacterial Vaginosis, Ovarian Cyst, Vaginitis / Bacterial Vaginosi
Medical Device or Treatment Issue	Cast Problem, Device Check, Dressing Change, Feeding Tube, AICD Problem, Insulin Pump Visit, Gastrostomy Tube Change, Medication Reaction, Shunt, Appliance Removal, Tube Problem, Urinary Catheter Change, Vascular Access Problem, Enteral Nutrition Evaluation, Device Malfunction, Pacemaker Problem, Remova / Exchange Catheter, Drain Removal, Outpatient Infusion, Treatment, Heart Assist Device, Stoma Dysfunction, Tracheostomy Tube Change, Ureteral Stent Exchange
Medication Request	Immunizations, Infusion / Injection Administration, IV Medication, Infusion/ Injection Administ, Med Refill, Medication Visit, Pain Management, Blood Product Administration, Labs Only, Tetanus (Td & Tdap), Wound Care
Neurological Issue	Altered Mental Status, Cognitive Concerns, Facial Droop, Pre Syncope, Focal Weakness, Headache, Memory Loss, Migraine, Dementia, Dysphasia, Neuro Problem, Numbness, Paralysis, Seizures, Slurred Speech, Spasms, Stroke Like Symptoms, Tingling, Tremors, Trigeminal Neuralgia, Unable to Speak, Seizure Disorder, Insomnia, Parkinson's Disease, Loss of Consciousness, Neuropathy, Ataxia, Unable to speak, Peripheral Neuropathy, Stroke, Cerebrovascular Accident, Speech Problem, Acute Neurological Problem, Flashes, Light, Unresponsive, Multiple Sclerosis, Parkinson's Disease, Febrile Seizure, Paresthesia, Peripheral Neuropathy, Hydrocephalus, Spasticity, Neuroendocrine Tumor
Other	Dehydration, Fisula Evaluation, Follow-Up, Illness, Letter for School/Work, Aneurysm, Lung Eval, Error, Mass, Oral Swelling, Other, Advice Only, Deformity, Electric Shock, Personal Problem, Shaking, Swelling, Swollen Glands, Adenopathy, Adrenal Problem, Thrombophilia, Weight Gain, Weight Loss, Hiccups, , Chemo Related Symptoms, Hot Flashes, Follow-up, Non Healing Wound, (Other), Mouth Injury, Xerostomia, Prostate Check, Suture / Staple Removal, Wellness, Voice Changes, Vital Sign Check, Coagulation Disorder, Cold Exposure, Consult, Dental Problem, Tetanus (Td & Tdap), Infusion/ Injection Administ, Tracheostomy Tube Change, Medical Information, Neutropenic Fever, Infection, Leukemia, Heat Exposure, Poor Appetite, Gingivitis, Pre-op Exam, gingivitis, Loss of appetite, Failure To Thrive, Referral, Lymphoma, Hot Flashes, Neutropenia, Radiation, Ingestion, TB Test, Fussy, Lupus, Toxic Inhalation, Lung Screening, Leakage/Loss of Fluid, Liver Eval, Hepatic Cancer, Lung Mass, Venous Thromboembolic Disease, Insulin Pump Visit, Preventive Visit, Avulsion, Peripheral Edema, Hypoglycemic Unawareness, Immobility, Giant Cell Arteritis, Polydipsia, Platelet Disorders, Post-procedure, Lung Follow-up, Poisoning, Injections, POTS, Insulin Reaction, Liver Transplant, Labs Only

Other Pain	Dental Pain, Facial Pain, Generalized Body Aches, Myalgia, Dental Injury, Jaw Pain, Muscle Pain, Neck Pain, Pain, Sickle Cell Pain Crisis, Paresthesia, Torticollis, Chronic Pain, Cancer Pain, Incisional Pain, Bone Pain, Tailbone Pain, Gout, Muscle pain/Weakness, Pseudogout
Post-Op Issue	Post-Op, Post-Procedure, Post-Op Problem, Post-op, Post-Op Issue, Wound Dehiscence, Post-op Problems, Post-op Problem
Psychiatric Complaints	Anxiety, Auditory Hallucinations, Depression, Panic Attack, Homicidal, PTSD (Post-Traumatic Stress, Delusional, Fussy, Paranoia, Suicide Attempt, Hallucinations, Manic Behavior, Eating Disorder, Suicidal, Agitation, Psychiatric Evaluation, Aggressive Behavior, Mental Health Problem, Inappropriate Words
Shortness of Breath	Airway Obstruction, Aspiration, Pain With Breathing, Near Drowning, Respiratory Distress, Shortness of Breath, Wheezing, Increased Work Of Breathing, Difficulty Breathing, Choking, Oxygen Dependence, Hyperventilating, Orthopnea
Skin Complaints	Abrasion, Abscess, Bleeding/Bruising, Blister, Angioedema, Lip Laceration, Burn, Cellulitis, Cyst, Drainage from Incision, Disturb of Skin Sens, Edema, Extremity Laceration, Facial Burn, Cyanosis, Impetigo, Facial Laceration, Facial Swelling, Finger Laceration, Leg Rash, Herpes Zoster, Hives, Itching, Jaundice, Diabetic Ulcer, Diabetic Wound, Laceration, Mouth Lesions, Non-Healing Wound, Rash, Recurrent Skin Infections, Skin Problem, Sore, Scabies, Suture \Staple Removal, Wound Check, Wound Infection, Lesion, Skin Check, Minor Skin Infection, Skin Ulcer, Skin Discoloration, Sunburn, Head Lice, Scabies, Fungal Infection, Leg Rash, Impetigo
Substance Abuse Issues	Alcohol Intoxication, Alcohol Problem, Withdrawal, Drug Overdose, Drug / Alcohol Dependency, Addiction Problem, Addiction Assessment, Delirium Tremens (DTS)
Upper Respiratory Symptoms	Congestion, Cough, Coughing Up Blood, Flu Symptoms, Enlarged Tonsils, Peritonsillar Abscess, Nasal Congestion, Sinus Symptoms, Sinusitis, Sore Throat, Hoarseness, Throat Problem, Upper Respiratory Infection, Influenza, Laryngitis, Respiratory Arrest, Pneumonia, Pleural Effusion, Asthma, Croup, URI, Peritonsillar Abscess
Pregnancy Related	Pregnancy Problem, Miscarriage, Contractions, Ectopic Pregnancy, Laboring, Possible Pregnancy, Pregnancy Related
Renal	Av Fistula, Kidney Transplant, Elevated Serum Creatinine, End-Stage Liver Disease, Hemodialysis Access, Nephritis, Ureteral Stent Exchange
Urinary Complaints	Bladder Problem, Blood in Urine, Cystitis, Difficulty Urinating, Dysuria, Gross Hematuria, Painful Urination, Urinary Frequency, Urinary Symptom, Urinary Incontinence, Urinary Problem, Urinary Retention, Slowing Urinary Stream, Urinary Tract Infection, Urinary Urgency, Voiding Dysfunction, Hesitancy Urinary

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Table 5 Regression Results by Chief Complaint

	CHIEF_COMPLAINT	Coefficient_Starred	P_value
1	Extremity Complaints	-0.72**	0.03
2	Upper Respiratory Symptoms	0.426**	0.02
3	Abnormal Test Results	-0.067	0.84
4	Falls, Motor Vehicle Crashes, Assaults, and Trauma	-0.423*	0.10
5	Shortness of Breath	-0.065	0.58
6	Gastrointestinal Issues	0.071	0.67
7	Chest Pain	0.107	0.68
8	Dizziness/Lightheadedness/Syncope	-0.163	0.32
9	Neurological Issue	-0.353	0.25
10	Fatigue and Weakness	-0.112	0.49
11	Back or Flank Pain	-0.602**	0.02
12	Abdominal Complaints	-0.105	0.13
13	Fevers, Sweats or Chills	0.01	0.95
14	Skin Complaints	1.442	0.35

Table 6 Regression Results by Chief Complaint (2)

	CHIEF_COMPLAINT	Coefficient_Starred	P_value
1	Extremity Complaints	0.176	0.50
2	Upper Respiratory Symptoms	0.332***	0.00
3	Abnormal Test Results	0.695	0.14
4	Falls, Motor Vehicle Crashes, Assaults, and Trauma	-0.247	0.20
5	Shortness of Breath	-0.253**	0.01
6	Gastrointestinal Issues	0.421***	0.00
7	Chest Pain	-0.531***	0.00
8	Dizziness/Lightheadedness/Syncope	0.075	0.60
9	Neurological Issue	-0.305	0.15
10	Fatigue and Weakness	-0.125	0.40
11	Back or Flank Pain	0.288	0.13
12	Abdominal Complaints	-0.023	0.66
13	Fevers, Sweats or Chills	-0.044	0.71
14	Skin Complaints	0.328	0.35

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Table 7 First Stage over Subsamples

	CHIEF_COMPLAINT	Coefficient_Starred	P_value
1	Extremity Complaints	0.761***	0.00
2	Upper Respiratory Symptoms	1.406***	0.00
3	Abnormal Test Results	1.036***	0.00
4	Falls, Motor Vehicle Crashes, Assaults, and Trauma	0.831***	0.00
5	Shortness of Breath	1.258***	0.00
6	Gastrointestinal Issues	1.043***	0.00
7	Chest Pain	0.866***	0.00
8	Dizziness/Lightheadedness/Syncope	1.668***	0.00
9	Neurological Issue	0.723***	0.00
10	Fatigue and Weakness	1.651***	0.00
11	Back or Flank Pain	0.752***	0.01
12	Abdominal Complaints	1.109***	0.00
13	Fevers, Sweats or Chills	1.23***	0.00
14	Skin Complaints	0.448*	0.07

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