

DATAWATCH

Heterogeneity in Physician Test Ordering Practices: Batched vs. Sequentially Ordering Diagnostic Tests

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An analysis of data from over 41,000 patient visits to the Emergency Department (ED) at the Mayo Clinic, Phoenix, AZ, reveal high variance in physician tendency to batch-order versus sequentially-order diagnostic tests within the same hospital. Among the reasons for a patient's visit to the ED, [insert chief complaint] had the greatest variability in test ordering practices and made up approximately [insert per-cent] of all ED visits during the study period. Test ordering strategies may play an important role in optimizing ED workflows, improving patient care, and reducing unnecessary costs in healthcare.

KEYWORDS:

Diagnostic Testing; Emergency Department; Operational Efficiency;

1 | INTRODUCTION

Emergency Departments (EDs) remain at the forefront of healthcare delivery, often grappling with inefficiencies that impact patient outcomes and the broader health system. One potential determinant of these inefficiencies lies in the diagnostic test-ordering practices of physicians. Drawing from data from over 41,000 ED visits at the Mayo Clinic of Arizona, we observed a pronounced variability in physicians' tendencies to batch-order or sequentially-order diagnostic tests. Interestingly, these variations persisted even among physicians practicing under the same guidelines within an identical hospital setting.

This variation was most palpable among prevalent chief complaints in the ED, such as abdominal issues and back pain. The data indicated that differences in test-ordering practices were not mere anomalies but were rooted in individual clinical judgment and preference (as depicted in Exhibit 1). Our preliminary findings underscore a potential imperative: crafting or refining guidelines that target test-ordering strategies, thereby optimizing ED operations, curbing unnecessary expenditures, and enhancing patient outcomes.

2 | STUDY DATA AND METHODS

Setting and Sample: 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.

Data Compilation: 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.

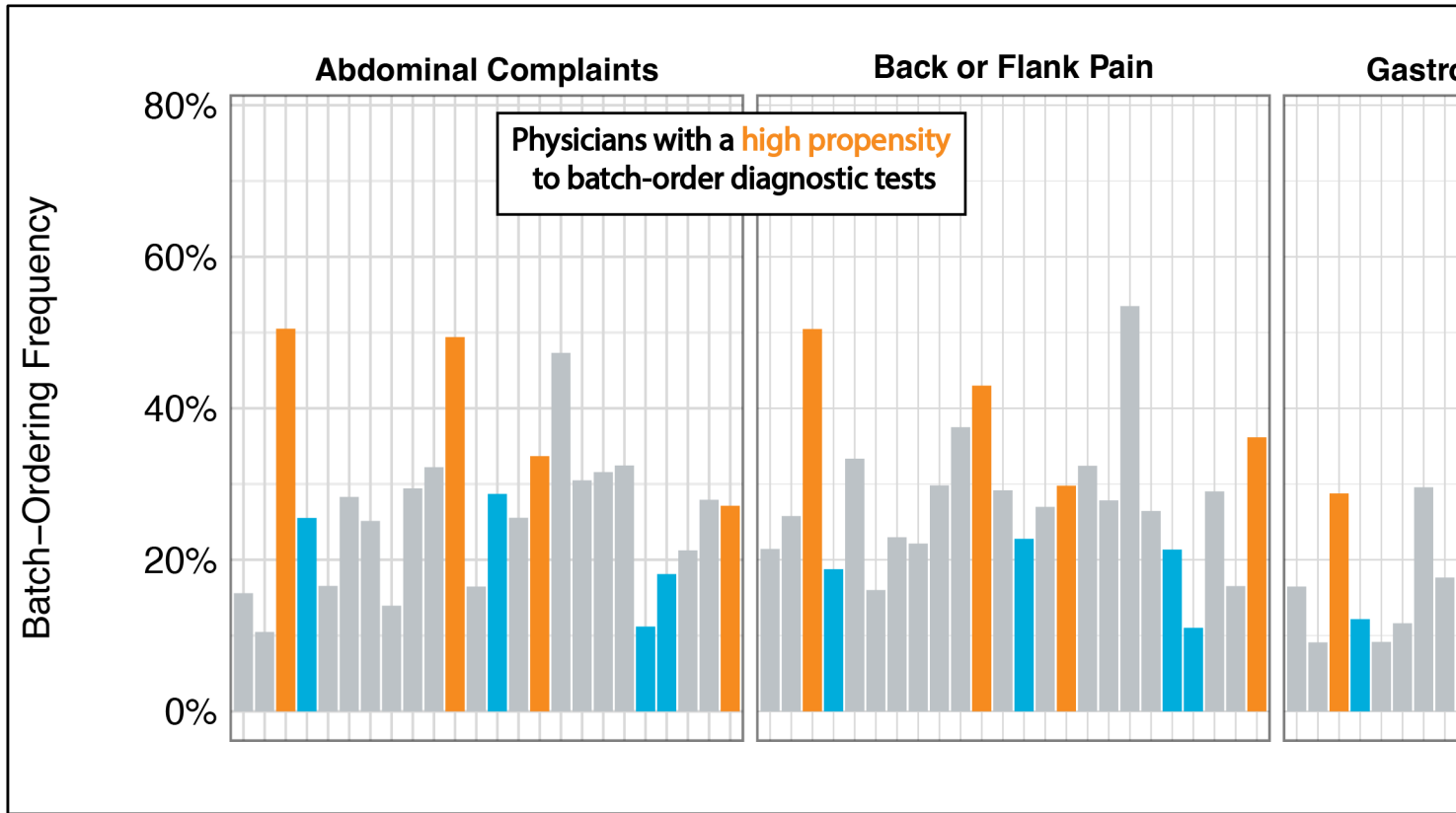


FIGURE 1 picture

Physician Assignment Process: Contrary to most healthcare settings where patients exhibit choice, in the ED, they are predominantly passive in their physician assignment. 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. Table 1 displays that patient encounters (in terms of chief complaints and emergency severity) are equitably distributed across physicians within our study's cohort.

3 | STUDY RESULTS

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.

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,

TABLE 1 Balance of Chief Complaints Across ED Providers: Results of Wald Test

Chief Complaints	F-Statistic	<i>Pr(> F)</i>
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
Chief Complaints	F-Statistic	<i>Pr(> F)</i>
ESI 1 or 2	1.09	0.346
ESI 3, 4, or 5	1.247	0.195

Notes: The Wald test was conducted to assess the balance of chief complaints across providers in our dataset. A balanced distribution implies that complaints 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.

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 2 Summary Statistics for Sequential vs. Batched Test Groups

Variable	Overall Visits, N = 41,197 ¹	Tests were Sequentially-Ordered, N = 23,4331	Tests were Batch-Ordered, 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

4 | DISCUSSION

5 | CONCLUSION

6 | APPENDIX

TABLE 3 Chief Complaints Categorization

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, Ear-ache, 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 Fatigue, 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, GI Bleeding, GI Problem, Hemorrhoids, Morning Sickness, Nausea, Ostomy Care, Rectal Bleeding, Rectal Pain, Vomiting, Vomiting Blood, Vomiting During Pregnancy, GI Bleeding, Fecal Incontinence, Bloating, Hematochezia, Urine Leakage, Heartburn, Rectal Discharge, Urolithiasis, Ulcerative Colitis, Irritable Bowel Syndrome, Rectal Prolapse, Fistula Evaluation, Rectal Problems, Perianal Abscess, Fistula 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 Vaginosis
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, Removal / 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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