# Bias on the Brain: How Patient Gender Influences Use of Emergency Room Diagnostic Imaging

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**Abstract**

Existing research suggests gender may influence rates of diagnostic imaging, which are crucial for managing health outcomes and costs in conditions that require a fast and accurate diagnosis. Given a strong consensus among quality guidelines that diagnostic head imaging is necessary for patients with suspected acute ischemic stroke, first-time seizure, and skull fracture, this paper examines whether gender influences the probability of imaging for patients with these three conditions in the emergency room. Because patients have little agency over their attending physician, using emergency room visits allows for quasi-randomization of patients to physicians. I hypothesize that being female results in a lower probability of head imaging and that female patient-female physician gender concordant encounters result in a higher probability of head imaging. By using OLS regression on U.S. nationwide medical claims data from 2014-2018, this paper finds a causal relationship between gender and head imaging utilization. Female patients with a diagnosis of acute ischemic stroke, first-time seizure, or skull fracture have a 6.68%, 2.88%, and 2.91% lower probability of receiving head imaging in the ER than male patients, respectively. I also find that gender concordance does not influence the probability of head imaging. These findings imply that increased gender-specific physician training is needed to close the gender gap and increase uniform adherence to imaging quality guidelines. Further research is also necessary to identify the underlying cause of gender disparities, such as physician gender bias, insufficient gender-specific emergency medicine training, and patient condition severity.

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## 1 Introduction

Stroke, seizure, and skull fracture are major drivers of morbidity and mortality in the United States. Stroke, for example, kills approximately 140,000 Americans each year, is the leading cause of long-term disability, and costs the U.S. an estimated $34 billion annually in direct health care costs and missed days of work (CDC 2020). 11% of Americans will have at least one seizure at some point in their life and seizures account for one million emergency room (ER) visits annually (Martindale et al. 2011; Pallin et al. 2008). Although the economic costs of seizures alone have not been well-researched, associated conditions like epilepsy cost the U.S. $9.6 billion in medical care costs each year (Cramer et al. 2013). Lastly, approximately 2.8 million people in the U.S. sustain head injuries annually, resulting in 2.5 million emergency evaluations and 60,000 deaths. Skull fractures are also a major risk factor for traumatic brain injury, which contributes to 30% of all injury-related deaths and has been increasing in frequency over time (Taylor et al. 2017).

An essential component in managing both the direct health outcomes and costs of all three of these conditions is diagnostic imaging. Diagnostic imaging is crucial for a variety of purposes: making an accurate diagnosis, determining a prognosis, assigning appropriate treatment, and ultimately improving immediate and long-term outcomes. Existing clinical research and quality guidelines from quality measure organizations like UpToDate and the National Quality Forum, as well as physician specialty societies such as the American College of Radiology, the American Society of Neuroradiology, the Society of NeuroInterventional Surgery, the American Academy of Neurology, the American Heart Association, and the American College of Emergency Physicians, are in consensus that a CT or MRI should be conducted same day for patients with suspected acute ischemic stroke, first-time seizure, or skull fracture.

Given the importance of diagnostic head imaging and existing research that suggests gender may play a role in the utilization of imaging, this paper focuses on the role that a patient's gender and patient-physician gender concordance play in complying with imaging guidelines. In particular, I look at whether being female and being female in the presence of a female physician has a causal relationship on the likelihood of receiving diagnostic head imaging. To capture this, I look at whether a head or brain CT or MRI is performed on an initial visit in the emergency room for patients with a diagnosis of acute ischemic stroke, first-time seizure, or skull fracture.

Because patients in the ER have little choice in their attending physician, observing imaging rates in the ER allows for the quasi-random assignment of physician and patient gender. Given the strong consensus that imaging should be conducted for stroke, seizure, or skull fracture regardless of patient gender, as well as the wide availability of imaging machines in emergency rooms, imaging seems an ideal procedure to use to identify gender disparities and potential bias in treatment decisions. Patient gender and physician-patient gender concordance are also of particular importance in the emergency room, given that women make up less than 25% of emergency-medicine trained physicians and the medical establishment is increasingly recognizing the need for gender-specific emergency medicine (Pallardy 2013; McGregor & Choo 2013).

I hypothesize that being a female patient results in a lower probability of head imaging due to factors including physician gender bias and lack of gender-specific training in treating women with stroke, seizure, and skull fracture. I also hypothesize that female patient – female physician gender concordant ER encounters result in a higher probability of head imaging because of prior research indicating better patient-physician communication, trust, treatment, and outcomes in gender concordant visits (Greenwood et al. 2018; Gross et al. 2008; Malhotra et al. 2017; Hall et al. 1994).

## 2 Imaging Guidelines and Background

Research and quality guidelines agree CT and MRI imaging should be conducted for all patients suspected of acute ischemic stroke, first-time seizure, and skull fracture. Head or brain imaging should be conducted for all patients with symptoms indicating acute ischemic stroke in order to make a definitive diagnosis, assess the severity of brain damage, exclude the possibility of hemorrhage, and identify the location and extent of clots for intravenous thrombolysis or other interventions (Schellinger et al. 2010; Birenbaum et al. 2011; Filho & Lansberg 2020; Wintermark et al. 2013; Latchaw et al. 2009). Tissue plasminogen activator (tPA), the gold standard treatment for ischemic stroke, is associated with significant decreases in mortality compared to patients not treated with tPA (28% decrease in mortality at 5 years, 37% decrease in mortality at 10 years) (Muruet et al. 2018). However, tPA is a highly time-dependent treatment that must be administered within 3 to 4.5 hours of stroke onset, with the greatest benefit to patients treated earlier (Latchaw et al. 2009). This makes rapid prioritization of imaging for stroke patients key for delivering the best treatment possible and reducing mortality rates.

Adults with unprovoked first seizure (no history of epilepsy) should have a CT or MRI done to identify any processes like lesions that may be responsible for the seizure (Lee et al. 2019; Gavvala & Schuele 2016; ACEP 2011; Harden et al. 2007; Bernal & Altman 2003; Crocker, Pohlmann-Eden, and Schmidt 2017). The imaging results also help physicians determine whether to pursue treatment with antiepileptic drugs and assess the risk of seizure recurrence, which is higher for first-time seizure patients seen in the ER (Garber & Galuser 2017).

Finally, patients with suspected skull fracture should receive a CT to make a diagnosis, identify possible traumatic brain injuries, and assess the need for neurological intervention. MRI is also used in instances where physicians need to detect subacute or chronic brain injuries and identify potential causes of symptoms not explained by CT findings (Shetty et al. 2016; Mutch & Talbott 2017; Demetriades & Kobayashi 2020; Jagoda et al. 2009).

## 3 Influence of Gender in Medicine

Previous studies have indicated gender differences in imaging, treatment, and outcomes for patients with stroke, seizure, head trauma, and related conditions with contradictory results. None have focused on the role of patient-physician gender concordance.

Gender differences in the use of imaging technologies or tests are well studied for stroke but excluded from most seizure, skull fracture, or head injury research. Some studies of stroke patients find women are undersupplied with imaging such as MRIs, echocardiography, carotid evaluations, general brain imaging, lipid testing, and electrocardiograms (Giralt et al. 2011; Smith et al. 2005; Reeves et al. 2008; Di Carlo et al. 2003; Kapral et al. 2009). Other studies find no gender difference in the use of neuroimaging or carotid imaging (Kapral et al. 2011; Hochner-Celnikier et al. 2005). Again, existing research has not looked at gender differences in the use of imaging for seizure or skull fracture or related conditions like epilepsy and traumatic brain injury (TBI).

For gender differences in treatment, studies of stroke patients have found women are less likely to receive antiplatelets, statins, angiotensin-converting enzyme inhibitors, thrombolysis therapy, carotid surgery, and carotid revascularization (Giralt et al. 2011; Kapral et al. 2011;

Reeves et al. 2008; Turtzo & McCullough 2008; Poisson et al. 2010; Kapral et al. 2009). Others find no gender differences in treatment with thrombolysis, oral anticoagulants, antiplatelet drugs, or rehabilitative services, and one finds women are more likely than men to receive antiplatelets at discharge (Asdaghi et al. 2016; Kapral et al. 2011; Holroyd-Leduc et al. 2000; Hochner-Celnikier et al. 2005; Turtzo & McCullough 2008). Gender differences have been found in the type of drug regimens prescribed to epilepsy and seizure patients, but most differences are explained by the impact of patient gender on drug tolerability and safety (Luef et al. 2015; Ettore et al. 2013; Kishk et al. 2019). Existing research on TBI, which is closely related to skull fracture, finds no gender differences in surgical management (Gao and Jiang 2012; Renner et al. 2012).

Gender differences in patient outcomes have been found in all three conditions. Some studies find female stroke patients have higher in-hospital mortality, higher 3-month and 1-year mortality, and poorer functional output (Hochner-Celnikier et al. 2005; Eriksson et al. 2009; Reeves et al. 2008). Others find equal readmission and mortality rates between men and women with stroke, and one finds women have a lower 1-year risk of mortality (Caso et al. 2010; Kapral et al. 2011; Holroyd-Leduc et al. 200). Studies of epilepsy outcomes find men report poorer physical function, experience more brain atrophy, and face higher mortality rates than women, possibly attributed to higher seizure frequency in men (Leidy et al. 1999; Gaus et al. 2014; Briellman et al. 2000). Another study has found the probability of long-term remission is similar in men and women (Ettore et al. 2013). Research on TBI has found black women are less likely to be hospitalized after evaluation in the ER and that women generally face higher rates of mortality and poorer outcomes (Welassie et al. 2004; Munivenkatappa et al. 2016; Farace & Alves 2000; Ng et al. 2006).

In summary, a significant amount of literature exists on gender differences related to diagnosis, treatment, and outcomes for patients with stroke, seizure, and fracture. However, the influence of gender on imaging utilization for stroke remains uncertain given conflicting results. Little research directly addresses anything related to first-time seizure or skull fracture, only associated conditions like epilepsy, head trauma, and TBI, and even for these conditions, little research focuses on the impact of gender on diagnostic imaging. Further, no studies on stroke or seizure and fracture-related conditions focus on the role of patient-physician gender concordance in the initial diagnostic encounter.

This paper will add to the existing literature by focusing on gender disparities in diagnostic imaging for first-time seizures and skull fracture and provide additional analysis to clarify contradictory findings for the role of gender in stroke imaging. This analysis will also add gender-concordance as a potential factor influencing imaging rates. By looking at gender differences in imaging utilization across multiple conditions in the ER, this paper can draw on larger claims data, with more heterogeneity in patients and physicians, than other papers that depend on samples limited to a few hundred patients recruited from singular facilities or by surveys (Oto et al. 2005; Leidy et al. 1999; Merode et al. 1997; Gaus et al. 2015; Briellmann et al. 2000; Burneo et al. 2008; Colantonio et al. 2010; Ng et al. 2006). Analysis with U.S. nation-wide medical claims also adds to the existing literature by studying a patient population with greater geographic, socioeconomic, and racial diversity compared with the facility or state-level data of many other studies.

## 4 Data

I base my analysis on a panel of administrative claims data that covers U.S. patient medical claims from 2014 – 2018, obtained from an independent nonprofit that collects and manages data for privately billed health insurance claims and integrates Medicare Parts A, B, and D claims data. The data contains all patient claims data from professional, outpatient, and inpatient settings for approximately 46.9 million distinct patients across 494 “geozips”, based on the first three digits of U.S. zip codes. Each claim is associated with a de-identified patient medical encounter and includes fields specifying a unique claim id, patient id, patient age, diagnosis codes (ICD-9 and ICD-10), procedure codes (CPT), National Provider Identifier (NPI) number (associated with an individual practitioner or healthcare facility), physician specialty, insurance type (Medicare, Medicaid, Workers’ Compensation, commercial), and date of service.

National Plan and Provider Enumeration System (NPPES) NPI registry data are used to obtain physician gender, a 5-digit zip code, and the date a physician receives their NPI number, which I use as a proxy for physician years of experience. NPPES NPI registry data is managed by the U.S. Centers for Medicare & Medicaid Services and includes all active National Provider Identifier records, updated monthly.

Physician medical school data is obtained by combining Medicare Physician Compare data with data web scraped from U.S. News and World Report’s Doctor search tool. Physician Compare data is also managed by the U.S. Centers for Medicare & Medicaid services and includes demographic information about individual eligible clinicians in Medicare, updated twice monthly.

I generate three samples from the data based on whether a patient has a claim with a diagnosis code for acute ischemic stroke, unexplained seizure (excludes patients with provoked seizures, seizures linked to other medical conditions, and patients with a history of epilepsy), or skull fracture on the same date as a CPT code for an emergency room visit (see Table 16 in the Appendix for the full list of codes). The primary rate of head imaging is calculated as whether a

CPT code for a head or brain CT or MRI occurs on the same date as the initial emergency room visit.

The raw rates of head imaging by gender show that women across all three conditions received imaging at rates 1 – 5% lower than men. The average rate across both genders of a patient receiving a head CT or MRI on the same day as the initial encounter is also lower than anticipated, at 39.52% for stroke patients, 45.12% for seizure patients, and 37.23% for skull fracture patients. The average age of men and women in each sample is approximately the same, with the exception of skull fracture. Similar to other research findings that women with head trauma tend to be older than men, the average age of women with skull fracture in this sample is 9.4 years older than the average age of men (Renner et al. 2012; Ng et al. 2006). There are more male patients and male physicians than women across all three sub-samples. Physicians have approximately the same average number of years of experience across all samples and genders (8.64 years), and the majority of patients in each sample are covered by commercial insurance.

**Table 1: Summary Characteristics of Patients Included in the Sample**

| | | Acute Ischemic Stroke | First-time Seizure | Skull Fracture |
|---|---|---|---|---|
| Same Day Imaging (Rate) | Female Patients | 36.50% | 43.31% | 36.99% |
| | Male Patients | 42.09% | 46.68% | 37.35% |
| Patient Gender (Count) | Female Patients | 46% | 9,426 | 35.07% |
| | Male Patients | 54% | 10,988 | 64.93% |
| Physician Gender = F (Rate) | Female Patients | 23.38% | 26.79% | 24.88% |
| | Male Patients | 23.06% | 28.08% | 25.37% |

| | | | | |
|---|---|---|---|---|
| Mean Age (Years) | Female Patients | 63.99 | 32.68 | 42.79 |
| | Male Patients | 62.91 | 32.18 | 33.39 |
| Mean Physician Experience (Years) | Female Patients | 8.66 | 8.55 | 8.75 |
| | Male Patients | 8.70 | 8.59 | 8.61 |
| Insurance Type (Count) | Commercial | 12,119 | 17,632 | 17,077 |
| | Medicare | 2,370 | 507 | 764 |
| | Medicaid | 485 | 1,871 | 970 |
| | Workers' Comp | 54 | 404 | 1,832 |

The dataset lacks several data elements that would be useful to include in this analysis. One is a patient's specific insurance carrier, which would influence a patient's out of pocket costs and physician network. Another is patient race, which has been found in other research to impact rates of imaging in the ER but is not collected by claims data (Martin et al. 2012; Shrager et al. 2019). Facility-level identification would also be useful to control for emergency room variation in staffing and availability of imaging machines. Because the analysis uses claims data instead of electronic health record (EHR) data, this is also no way of controlling for factors such as a patient's condition severity or their time from symptom onset to clinical evaluation, both of which ideally should not influence adherence to imaging guidelines but in reality, potentially affect a physician's prioritization of imaging. For example, clinical assessment with tools such as the Glasgow Coma Scale (GCS) is a cornerstone of head trauma evaluation to determine symptomology and severity of TBI, but although ICD codes for GCS scores exist, they are not uniformly observed in claims data and cannot be included as controls (Mutch & Talbott 2017).

Lack of EHR data also prevents controlling for risk factors beyond comorbidities such as smoking, alcohol use, and family medical history.

Claims missing variables of interest that cannot be filled by matching data from other claims using patient id or NPI are dropped from the analysis. Because claims data lack time indicators, it is also impossible to attribute a patient's ER encounter to an initial or primary attending physician if they have multiple claims listing different physicians on the same date. In order to control for patient gender and establish patient-physician gender concordance, the sample is restricted to patients with the same physician listed on their claims. Compared with patients included in the analysis, patients dropped from the sample are less likely to be covered by commercial insurance and more likely to be covered by Medicare and Workers' Compensation. Dropped patients are also treated at higher rates by NPIs that were female and had fewer years of experience. Table 12 in the Appendix shows the full characteristics of patients dropped from the sample.

## 5 Methodology

This paper utilizes a quasi-randomized identification process in which I leverage ER visits to randomly assign patients to physicians. I focus on ER visits because it creates a discrete encounter between a patient and physician where imaging is an immediate observable outcome that can be attributed to the physician and the patient's condition. ERs also generally assign patients to physicians in one of the following ways: a provider self-assigns to a patient, a designated provider assigns patients to a physician, or physicians alternate patients in a planned rotation (Traub et al. 2016). In any of these methods, patients have little choice in their ER physician, allowing for quasi-random assignment of patients and physicians. This eliminates patient preference for physicians and prevents bias associated with patients choosing physicians based on gender, experience, or other factors. Quasi-random assignment of patients to physicians using ER visits is also used in Greenwood et al. 2018 to study patient gender disparities in heart attack survival rates, Parys 2016 to study variation in physician practice styles, and Gowrisankaran, Joiner, and Léger 2017 to study emergency department resource use and health outcomes. Similar quasi-random assignment of patients to triage nurses is used in Woodworth & Holmes 2019 to study the effects of wait time on costs of care.

The proposed empirical strategy uses OLS regression to explore a causal relationship between patient gender, patient-physician gender concordance, and the probability of receiving head imaging. The benchmark equation estimated is:

$$(1) \quad Imaging_i = \beta_0 + \beta_1 F_i + \beta_2 PhyF_{ij} + \beta_3 F_i \times PhyF_{ij} + \beta_4 Age_i + \beta_5 MDC_i + \beta_6 MC_i + \beta_7 WC_i + \beta_8 Exp_{ij} + Year_t + Spec_{ij} + Zip\ Code_i + Comorbidities_i + Med\ School_{ij} + u_{itj}$$

Where $Imaging_i$ is a binary variable (0 if patient *i* did not receive a head or brain CT or MRI same-day, 1 if patient *i* did receive a head or brain CT or MRI same-day); $F_i$ is a binary gender variable (0 if male, 1 if female) for patient *i*; $PhyF_{ij}$ is a binary gender variable (0 if male, 1 if female) for physician *j* treating patient *i*; $F_i \times PhyF_{ij}$ is an interaction variable between female patient *i* and female physician *j*; $Age_i$ is the age in years for patient *i*; $MDC_i$, $MC_i$, and $WC_i$ are categorical variables indicating whether patient *i* has Medicare, Medicaid, or Workers' Compensation compared with commercial insurance; and $Exp_{ij}$ is the number of years physician *j* treating patient *i* has had their NPI number, which is used as a proxy for years of experience. The equation also includes year ($Year_t$), physician specialty ($Spec_{ij}$), zip code ($Zip\ Code_i$), comorbidity ($Comorbidities_i$), and medical school ($Med\ School_{ij}$) fixed effects. All estimates use robust standard errors.

My outcome variable of interest is whether a patient reporting to the ER with a diagnosis of acute ischemic stroke, first-time seizure, or skull fracture received a guideline specified diagnostic head or brain CT or MRI on the same day as the initial visit. Because the sample is based on patients who received a diagnosis of seizure, stroke, or skull fracture rather than patients who presented with potential symptoms, every patient met criteria indicating head imaging was appropriate. Analysis in later sections will also examine whether expanding the time window for imaging beyond the same day as the initial visit impacts findings.

Year of service fixed effects are included to control for time-specific variations year-to-year that can affect physician utilization of imaging, such as changes to diagnostic criteria and guidelines or increased availability of CT and MRI equipment. Service zip code fixed effects are included to control for geographical variation, such as physician and emergency room density and availability of emergency ambulance services. Specialty fixed effects are included to account for specialty-specific variation in training, diagnostic approach, and years of residency and fellowship. Medical school fixed effects are included to account for medical school-specific variation in training. Medical school fixed effects also restrict the sample to patients evaluated by a D.O. or M.D. and drop patients from the analysis whose claims only indicate treatment by nurse practitioners or physician assistants. Patient comorbidity fixed effects, based on the comorbidities included in the Charlson Comorbidity Index and the most common chronic conditions in the U.S., are included to control for variation in patient health and potentially help control for health service utilization (see Table 14 for the full list of comorbidities).

If the model is in line with the hypothesis that being a female patient results in a lower probability of head imaging, the coefficient $\beta_1$ on patient gender will be negative. If the model is in line with the hypothesis that patient-physician gender concordance results in a higher probability of head imaging, the coefficient $\beta_3$ on female patient – female physician gender concordance will be positive.

## 6 Results

Table 1 provides the estimated coefficients for regressions run using equation 1 for patients with a diagnosis of acute ischemic stroke, first-time seizure, or skull fracture.

**Table 2: Main Regression Results**

| VARIABLES | (1)<br>Stroke Imaging | (2)<br>Seizure Imaging | (3)<br>Fracture Imaging |
|---|---|---|---|
| Patient Female | -0.0668***<br>(0.0107) | -0.0288***<br>(0.00914) | -0.0291***<br>(0.00931) |
| Physician Female | 0.00450<br>(0.0159) | -0.0170<br>(0.0125) | 0.00887<br>(0.0117) |
| Patient Female x Physician Female | 0.0136<br>(0.0218) | -0.00636<br>(0.0170) | -0.0108<br>(0.0183) |
| Patient Age | -0.000777*<br>(0.000402) | 0.00240***<br>(0.000236) | 0.00246***<br>(0.000236) |
| Insurance Type (Medicare) | -0.0481***<br>(0.0165) | -0.0912***<br>(0.0305) | 0.107***<br>(0.0248) |
| Insurance Type (Medicaid) | 0.00843<br>(0.0470) | -0.0541**<br>(0.0260) | 0.0597*<br>(0.0318) |
| Insurance Type (Work Comp) | -0.154<br>(0.171) | -0.158***<br>(0.0522) | -0.00896<br>(0.0318) |
| Physician Years of Experience | -0.00251<br>(0.00268) | -0.00271<br>(0.00226) | -0.00228<br>(0.00225) |
| Constant | 0.449***<br>(0.0855) | 0.544***<br>(0.0663) | 0.388***<br>(0.0614) |
| Year Fixed Effects | Yes | Yes | Yes |
| Specialty Fixed Effects | Yes | Yes | Yes |

| | | | |
|---|---|---|---|
| Zip Code Fixed Effects | Yes | Yes | Yes |
| Comorbidity Fixed Effects | Yes | Yes | Yes |
| Med School Fixed Effects | Yes | Yes | Yes |
| Observations | 15,028 | 20,414 | 20,643 |
| R-squared | 0.241 | 0.199 | 0.208 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The negative coefficient on $F_i$ supports the hypothesis that female patients have a lower probability of receiving head imaging across all three conditions. Being a female patient generates a 6.68%, 2.88%, and 2.91% decrease in the probability that a head or brain CT or MRI is conducted in the ER on the same day compared to being male for stroke, first-time seizure, and skull fracture diagnoses respectively. These results are significant at 1%. The coefficients on $PhyF_{ij}$ are not significant for any diagnosis, indicating that seeing a male physician compared to a female physician does not change the probability of a patient receiving head imaging. The coefficients on $F_i \times PhyF_{ij}$ are also not significant for any diagnosis, indicating that gender concordant encounters do not increase the probability of a patient receiving head imaging. This is counter to my initial hypothesis that gender-concordant encounters would increase the probability of a patient receiving head imaging. The insignificance of gender-concordance may indicate that factors associated with gender-concordance such as increased communication and trust are not present in the sample or do not influence the decision to assign a patient imaging.

The regression results also find that moving from commercial insurance to Medicare generates a 4.81% (stroke), 9.12% (seizure), and 10.7% (skull fracture) decrease in the probability of receiving head imaging. These results are significant at 1%. For seizure patients, moving from commercial insurance to Medicaid or Workers' Compensation also generates a

5.41% decrease and a 15.8% decrease in the probability of receiving head imaging, significant at 5% and 1%. For skull fracture patients, moving from commercial insurance to Medicaid generates a 5.97% decrease in the probability of receiving head imaging, significant at 10%. The finding that patients with commercial insurance tend to have a higher probability of head imaging than patients with other insurance types may be a result of commercial insurance plans having higher in-network allowed amounts. Analysis of 2017 state-level in-network rates for people with employer-sponsored insurance and Medicare found that employer-sponsored insurance had allowed amounts that were 1.1 to 4.1 times greater than Medicare for radiology procedures (Hargraves & Biniek 2019). Another analysis has also found that private insurers paid hospitals on average 236% of Medicare rates in 2015, increasing to 241% of Medicare rates by 2017 (White & Whaley 2019).

A one-year increase in a patient's age results in a 0.24% and 0.246% increase in the probability of head imaging for seizure and skull fracture patients respectively, significant at 1%. For stroke patients, a one-year increase in a patient's age results in a -0.078% decrease in the probability of receiving head imaging, significant at 10%. Although these results are significant, the percentage change in the probability of head imaging is very small. Increased age has been found to increase the likelihood of imaging in other studies and can potentially be explained by older patients having greater risk factors and severity of illness (Smith-Bindman et al. 2012). The finding that increased age decreases the probability of imaging for stroke patients is counter to expectations and may be the result of the relative rarity of stroke among young people. For instance, physicians may elect for higher rates of imaging among young patients with symptoms of stroke because of increased uncertainty that stroke is the true underlying cause.

Physician years of experience is insignificant in these findings, indicating that more experienced physicians are not more or less likely than less experienced physicians to order head imaging. This may run counter to expectations that experience increases physician adherence to guidelines.

## 7 Robustness Checks

### 7.1 Imaging Time Frame

Patient time of arrival to the ER is a potential confounder when using same day head imaging as the dependent variable. If women tend to arrive at the ER later in the day than men, head imaging for women would more likely to take place on the next day even if the time from arrival to imaging is the same between men and women. To examine this possibility, I run regression equation 1 using a binary variable for head imaging: 0 if a patient did not receive a head or brain CT or MRI on the same or next day as their initial ER claim, and 1 if a patient did receive a head or brain CT or MRI on the same or next day as their initial ER claim. Although imaging is specifically recommended to occur as soon as possible for seizure, stroke, and skull fracture patients, I also run regression 1 using a binary variable: 0 if a patient did not receive a head or brain CT or MRI within 7 days of their initial ER claim, and 1 if a patient did receive a head or brain CT or MRI within 7 days of their initial ER claim. This may capture patients whose initial symptoms were less severe and chose to delay imaging. Tables 3 – 5 in the Appendix show these regression results for each condition.

The coefficient on patient gender remains significant and negative across conditions after using same or next day imaging as the dependent variable. The coefficient increases by 6.59% for stroke to -0.0624, increases by 19.44% for seizure patients to -0.0232, and decreases by 15.46% to -0.0336 for skull fracture patients. The results for stroke and fracture are significant

1%, while the result for seizure is significant at 5%. The coefficients on physician gender and patient-physician gender concordance remain insignificant for all conditions. These findings imply that the negative effect of being a female patient on the probability of head imaging improves for stroke and seizure patients after also accounting for next day imaging, while the negative effect worsens for skull fracture patients after accounting for next day imaging.

The coefficient on patient gender again remains significant and negative across conditions after using imaging within 7 days as the dependent variable. Compared to the initial same-day imaging regression, the coefficient on patient gender increases by 4.04% for stroke patients to -0.0641, increases by 38.19% for seizure patients to -0.0178, and decreases by 12.37% for skull fracture patients to -0.0327. The results for stroke and fracture are significant at 1%, while the result for seizure is significant at 10%. The coefficients on physician gender and patient-physician gender concordance remains insignificant for all conditions. Again, extending the imaging window to one week alleviates the negative effect of being a female patient on head imaging for stroke and seizure patients while worsening the effect for skull fracture patients.

For seizure and stroke patients, the finding that extending the imaging time window decreases the gender gap in the probability of imaging may have multiple implications. One possibility is that in line with the initial theory, women with stroke or seizure report to the ER at later times of the day than men are therefore more likely to receive imaging on the next day. Another possibility is that the severity of symptoms is less strong in women in the sample, and the physician or patient therefore chose to delay imaging until a follow-up appointment. This is far more reasonable for patients with first-time seizures than patients with stroke, as stroke patients should receive immediate treatment regardless of perceived severity. Patients with first-time seizures often don’t receive any immediate treatment and require follow-up appointments to determine appropriate drug therapies or other interventions. Another possibility is the severity of seizure and stroke is the same in both genders and bias in the attending or initial ER physician results in women only receiving imaging after evaluation by subsequent physicians. Finally, differences in patient behavior may result in higher rates of imaging for women at later dates, such as if male patients are more likely to demand imaging or question their diagnosis during the initial encounter or if female patients are more likely to pursue follow-up care.

For fracture patients, the finding that extending the imaging time window worsens the gender gap for the probability of imaging may imply that men are more likely to pursue follow-up care or women have higher rates of minor skull fracture that physicians determine do not require imaging.

Overall, expanding the time window for imaging fails to eliminate the finding that female patients have lower probabilities of receiving head imaging. Although factors like symptom severity or rate of follow-up care may result in higher rates of imaging for women on a later date, immediate imaging is still of crucial importance and disparities indicate the need for intervention.

### 7.2 Age

Existing research has found that gender differences in treatment and diagnosis of stroke, seizure, and skull fracture may be the result of age differences in men and women at the time of diagnosis. Although age is accounted for in regression equation 1, I further examine this possibility by stratifying each individual sample into quartiles of even sizes by age.

Table 6 in the Appendix shows that stratifying stroke patients in the sample into quartiles by age and running regression 1 results in a less negative, insignificant coefficient on patient gender for patients in the third quartile (age 63 – 73). The effect of gender on the probability of barely changes for patients in the first quartile (age 0 – 54). Female patients in the first quartile have a -6.63% probability of receiving imaging compared to male patients, a mere 0.75% increase from the coefficient on patient gender in the all-ages regression. This result is significant at 5%. The effect of being female on the probability of imaging worsens for patients in the second and fourth quartile (age 55 – 62 and 74+). Female patients in the second quartile have a -7.88% probability of receiving imaging compared to male patients, a 17.96% worse effect compared to the all-ages regression. This result is significant at 1%. Female patients in the fourth quartile have a -10.1% probability of receiving imaging compared to male patients, a 51.2% worse effect compared to the all-ages regression. This result is also significant at 1%.

Table 7 in the Appendix shows that stratifying seizure patients by age quartile and running regression 1 results in less negative, insignificant coefficients in the first three quartiles (age groups 0 – 17, 18 – 28, and 29 – 47). The effect of gender on the probability of imaging worsens for patients the last quartile (age 48+). Female patients age 48 or older, compared to male patients, have a -4.29% probability of receiving imaging. This result, significant at 10%, worsens the impact of being a female patient on the probability of imaging by 48.96%.

Table 8 in the Appendix shows that stratifying skull fracture patients in the sample into quartiles by age and running regression 1 results in patient gender having a less negative and insignificant effect on the probability of imaging for patients in the first and fourth quartile (age 0 – 20 and 54+). The effect of being female on the probability of imaging worsens for patients in the second and third quartile (age 21 – 31 and 32 - 53). Female patients in the second quartile have a -5.63% probability of receiving imaging compared to male patients, a 93.47 % worse effect compared to the all-ages regression. This result is significant at 1%. Female patients in the fourth quartile have a -6.67% probability of receiving imaging compared to male patients, a 129.21% worse effect compared to the all-ages regression. This result is also significant at 1%.

Stratifying the samples into quartiles by age show that the negative impact of being female on the probability of head imaging worsens for certain age groups and improves or becomes entirely insignificant for others. For stroke patients, the effect of female patient gender on the probability of head imaging worsens for patients in the second and fourth quartile (age 55 – 62, age 74+), is unchanged for patients in the first quartile, and becomes insignificant for patients in the last quartile. For first-time seizure patients, the effect of female patient gender on the probability of head imaging worsens for patients in the last quartile (age 48+) and becomes insignificant for all other quartiles. For skull fracture patients, the effect of female patient gender on the probability of head imaging worsens for patients in the second and third quartile (age 21 – 31, age 32 – 53) and becomes insignificant for patients in the first and fourth quartile.

It's unclear what conclusions can be drawn from these findings. The age quartiles where the effect of gender on the probability of imaging worsens vary between conditions. This may indicate that factors related to age that are specific to the condition, such as perceived risk by physicians and patient comorbidities that are not controlled for in the regression, worsen the gender disparity in imaging. In the case of first-time seizure and stroke, there may be fewer gender disparities in imaging among younger patients because there is more ambiguity in potential underlying causes. Physicians, facing more ambiguity and a wider range of probable diagnoses, may elect to image women at similar rates as men. For skull fracture patients, increased age may be related to more severe fractures or greater risk of brain trauma, raising a physician's willingness to conduct thorough imaging and resulting in lower gender disparities.

## 8 Discussion

The results of this paper find a causal relationship between patient gender and probability of head imaging in the emergency room. For patients with acute ischemic stroke, first-time seizure, or skull fracture, being female leads to a reduced likelihood of receiving diagnostic head imaging on the same day. Additional analysis also finds being female leads to a reduced likelihood of receiving head imaging anytime within seven days of being seen in the emergency room. These results support the existing literature that finds gender differences in imaging rates for patients with stroke. It also fills the current research gap in the effect of gender on imaging for patients with first-time seizure or skull fracture. Furthermore, against expectations, this paper finds that patient-physician gender concordance does not increase the probability of head imaging. Because this runs contrary to existing research that gender-concordance influences patient treatment through factors like increased trust and communication, further research should examine the mechanisms through which gender-concordance might influence imaging decisions in the ER.

Several potential confounders could not be controlled for in this analysis. One is patient symptom severity. Based on research that finds baseline stroke severity does not differ by gender or is worse in women, controlling for symptom severity is unlikely to change the findings for stroke patients or should worsen the gender disparity (Caso et al. 2010; Hochner-Celnikier et al. 2005; Eriksson et al. 2009; Giralt et al. 2011). Injury severity for skull fracture has not been compared between men and women, but findings for traumatic brain injury indicate no difference in severity by gender or worse manifestation of symptoms in women (Renner et al. 2012; Munivenkatappa et al. 2016). Gender differences in the severity of unprovoked seizures is also poorly researched, although the incidence of seizures is higher in men than women, indicating that severity may play a role in seizure imaging disparities between genders (Luef &

Taubøll 2015; Kotsopoulos et al. 2002; Briellmann et al. 2000). Analysis with health record data would be necessary to fully control for condition severity and assess its impact on imaging decisions.

Factors that influence outcomes such as pre-hospital delays, means of arrival to the ER, and time to evaluation are not controlled for in this analysis but are also unlikely to impact these findings. Research conflicts on whether women with stroke experience greater pre-hospital delays and time to evaluation, but delays should primarily affect time-sensitive treatment decisions like rates of tPA and outcomes (Madsen et al. 2016). Similar research has not been conducted for seizure or skull fracture but in both cases, the necessity of imaging is not changed by time from symptom onset. Evaluation with CT and MRI is found to be more likely for stroke patients transferred by ambulance compared with other modes of arrival but results also show gender is not associated with rates of ambulance use (Mohammad 2008; Govindarajan et al. 2013; Tataris et al. 2014).

A factor that may influence physician decision making for imaging is gender differences in ER utilization. Research has found women are 41% more likely than men to have a nonurgent ER visit and in California, women have the highest rates of ER use (McCormack et al. 2017; McConville et al. 2019). If women are using the ER at higher rates than men, especially for non-urgent concerns, physicians may be biased to believe that a female patient is exaggerating their symptoms and does not require advanced imaging even if they present with symptoms indicating the need for imaging. This possibility would still indicate gender bias by the physician.

A major limitation of this paper is that the samples are restricted to patients who receive a diagnosis of first-time seizure, acute ischemic stroke, or skull fracture rather than patients who present with symptoms indicating one of these conditions. Although restricting to patients who receive a diagnosis ensures that every patient in the sample should have received an imaging test, it may bias the results if patients who receive imaging are more likely to subsequently receive a diagnosis based on the imaging finding. It may also bias the analysis by excluding patients who are misdiagnosed or receive an imaging test that indicates another condition, especially in the case of stroke where women tend to be disproportionately underdiagnosed (Newman-Toker et al. 2014). Further analysis should anchor inclusion on patient symptoms or control for indications in health records data that show whether a diagnosis was assigned as the result of imaging findings.

This analysis is limited in its ability to risk-adjust for patient characteristics unobserved in claims data. Patient factors like race, education, and income may be confounding variables as they are likely to interact with gender and influence imaging decisions. Implicit racial bias, for instance, has been found to significantly relate to patient-provider interactions, treatment decisions, adherence to treatments, and outcomes (Hall et al. 2015). Implicit preference has also been found in medical students for upper-class patients (Haider et al. 2011). Race, education, and economic class also affect broader social determinants of health such as availability of housing, access to food, safe working conditions, and health literacy. These may influence patient comorbidities, access to care, condition severity, and patient decision making. Future analysis would ideally examine whether these factors interact with gender to affect the probability of imaging, for instance, whether black, low-income, or high-school educated women are less likely than white, high-income, highly educated women to receive imaging.

Future analysis could also further control for physician skill beyond factors like years of experience and medical school. Physician factors such as residence quality or board certification may also influence adherence to guideline imaging measures. Physician skill could also be controlled for by looking at adherence to other, unrelated quality measures.

This analysis concentrates on head or brain CT or MRIs. Future analysis could include a broader range of recommended diagnostic imaging to examine whether gender disparities are consistent across multiple imaging types. For example, carotid artery evaluation, echocardiography, and EKG are all recommended in addition to a CT or MRI for stroke patients. EEG is also recommended for seizure patients and x-rays can potentially be used for diagnosis of skull fracture.

Finally, the causal relationship established by these findings does not explain the underlying mechanism driving gender disparities. Further research is necessary to identify whether the gender gap in imaging is driven by physician gender bias, lack of education on imaging guidelines, patient election for imaging, or clinical factors like symptom presentation and severity.

## 9 Conclusion

This paper uses OLS regression and U.S. claims data over 5-years to demonstrate a causal relationship between patient gender and probability of head imaging. The results, controlling for year, zip code, physician specialty, patient comorbidities, and physician medical school, find that female stroke, seizure, and skull fracture patients have a 6.68%, 2.88%, and 2.91% lower probability of receiving head imaging in the ER compared to male patients, respectively. It also finds that physician gender and patient physician gender-concordance do not significantly affect the probability of head imaging.

These findings have important implications. Treatment decisions can be highly influenced by imaging findings, indicating that female patients are also more likely to receive poorer treatments and have worse outcomes. The overall lower rates of imaging for female patients means physicians are making treatment decisions for many women without any imaging guidance. Changes are necessary to improve adherence to guideline-recommended imaging procedures and reduce gender disparities in imaging utilization. The use of clinical decision tools that standardize the approach to risk stratification and potentially reduce subjective bias could significantly reduce these disparities. Similar mandatory computerized clinical decision support tools have been found to improve gender disparities in treatments like VTE prophylaxis prescriptions (Lau et al. 2015). Physician education and training should also focus on increased awareness of gender disparities in adherence to quality guidelines and improve understanding of gender-specific emergency medicine. Finally, further research is needed to explore the underlying causes of imaging gender disparities and develop targeted policy interventions.

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## 10 Appendix

### 10.1 Regression Results

Table 3: Stroke Imaging Regression Results by Time Window

| VARIABLES | (1)<br>Received Imaging<br>Same Day | (2)<br>Received Imaging<br>Same or Next Day | (3)<br>Received Imaging<br>Within One Week |
|---|---|---|---|
| Patient Female | -0.0668*** | -0.0624*** | -0.0641*** |
| | (0.0107) | (0.0109) | (0.0110) |
| Physician Female | 0.00450 | 0.00725 | 0.0108 |
| | (0.0159) | (0.0163) | (0.0162) |
| Patient Female x Physician Female | 0.0136 | 0.00123 | 0.00107 |
| | (0.0218) | (0.0225) | (0.0224) |
| Patient Age | -0.000777* | -0.000444 | -0.000333 |
| | (0.000402) | (0.000418) | (0.000417) |
| Insurance Type (Medicare) | -0.0481*** | -0.109*** | -0.124*** |
| | (0.0165) | (0.0171) | (0.0172) |
| Insurance Type (Medicaid) | 0.00843 | 0.00856 | 0.0164 |
| | (0.0470) | (0.0474) | (0.0467) |
| Insurance Type (Work Comp) | -0.154 | 0.0130 | 0.0239 |
| | (0.171) | (0.193) | (0.192) |
| Physician Years of Experience | -0.00251 | -0.00244 | -0.00249 |
| | (0.00268) | (0.00275) | (0.00274) |
| Constant | 0.449*** | 0.464*** | 0.484*** |
| | (0.0855) | (0.0849) | (0.0865) |
| Year Fixed Effects | Yes | Yes | Yes |
| Specialty Fixed Effects | Yes | Yes | Yes |
| Zip Code Fixed Effects | Yes | Yes | Yes |
| Comorbidity Fixed Effects | Yes | Yes | Yes |
| Med School Fixed Effects | Yes | Yes | Yes |
| Observations | 15,028 | 15,028 | 15,028 |
| R-squared | 0.241 | 0.235 | 0.236 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Seizure Imaging Regression Results by Time Window

| VARIABLES | (1) Received Imaging Same Day | (2) Received Imaging Same or Next Day | (3) Received Imaging Within One Week |
|---|---|---|---|
| Patient Female | -0.0288*** | -0.0232** | -0.0178* |
| | (0.00914) | (0.00918) | (0.00919) |
| Physician Female | -0.0170 | -0.00873 | -0.00519 |
| | (0.0125) | (0.0125) | (0.0126) |
| Patient Female x Physician Female | -0.00636 | -0.00353 | -0.00577 |
| | (0.0170) | (0.0172) | (0.0173) |
| Patient Age | 0.00240*** | 0.00252*** | 0.00233*** |
| | (0.000236) | (0.000238) | (0.000239) |
| Insurance Type (Medicare) | -0.0912*** | -0.116*** | -0.105*** |
| | (0.0305) | (0.0304) | (0.0304) |
| Insurance Type (Medicaid) | -0.0541** | -0.0565** | -0.0517* |
| | (0.0260) | (0.0263) | (0.0267) |
| Insurance Type (Work Comp) | -0.158*** | -0.180*** | -0.180*** |
| | (0.0522) | (0.0539) | (0.0540) |
| Physician Years of Experience | -0.00271 | -0.00332 | -0.00363 |
| | (0.00226) | (0.00227) | (0.00228) |
| Constant | 0.544*** | 0.541*** | 0.539*** |
| | (0.0663) | (0.0653) | (0.0651) |
| Year Fixed Effects | Yes | Yes | Yes |
| Specialty Fixed Effects | Yes | Yes | Yes |
| Zip Code Fixed Effects | Yes | Yes | Yes |
| Comorbidity Fixed Effects | Yes | Yes | Yes |
| Med School Fixed Effects | Yes | Yes | Yes |
| Observations | 20,414 | 20,414 | 20,414 |
| R-squared | 0.199 | 0.199 | 0.193 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Skull Fracture Imaging Regression Results by Time Window

| VARIABLES | (1)<br>Received Imaging<br>Same Day | (2)<br>Received Imaging<br>Same or Next Day | (3)<br>Received Imaging<br>Within One Week |
|---|---|---|---|
| Patient Female | -0.0291*** | -0.0336*** | -0.0327*** |
| | (0.00931) | (0.00937) | (0.00939) |
| Physician Female | 0.00887 | 0.0101 | 0.0101 |
| | (0.0117) | (0.0118) | (0.0118) |
| Patient Female x Physician Female | -0.0108 | -0.00816 | -0.00842 |
| | (0.0183) | (0.0185) | (0.0185) |
| Patient Age | 0.00246*** | 0.00264*** | 0.00263*** |
| | (0.000236) | (0.000238) | (0.000238) |
| Insurance Type (Medicare) | 0.107*** | 0.0986*** | 0.0967*** |
| | (0.0248) | (0.0248) | (0.0248) |
| Insurance Type (Medicaid) | 0.0597* | 0.0614* | 0.0691** |
| | (0.0318) | (0.0321) | (0.0321) |
| Insurance Type (Work Comp) | -0.00896 | -0.0127 | -0.0182 |
| | (0.0318) | (0.0319) | (0.0319) |
| Physician Years of Experience | -0.00228 | -0.00319 | -0.00321 |
| | (0.00225) | (0.00227) | (0.00227) |
| Constant | 0.388*** | 0.383*** | 0.382*** |
| | (0.0614) | (0.0620) | (0.0620) |
| Year Fixed Effects | Yes | Yes | Yes |
| Specialty Fixed Effects | Yes | Yes | Yes |
| Zip Code Fixed Effects | Yes | Yes | Yes |
| Comorbidity Fixed Effects | Yes | Yes | Yes |
| Med School Fixed Effects | Yes | Yes | Yes |
| Observations | 20,643 | 20,643 | 20,643 |
| R-squared | 0.208 | 0.211 | 0.210 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6: Stroke Age Stratification Regression Results by Quartile

| VARIABLES | (1) Stroke Imaging (All Ages) | (2) Stroke Imaging (Age 0 – 54) | (3) Stroke Imaging (Age 55 – 62) | (4) Stroke Imaging (Age 63 – 73) | (5) Stroke Imaging (Age 74+) |
|---|---|---|---|---|---|
| Patient Female | -0.0668*** | -0.0663** | -0.0788*** | -0.0399 | -0.101*** |
| | (0.0107) | (0.0260) | (0.0276) | (0.0278) | (0.0295) |
| Physician Female | 0.00450 | -0.00189 | -0.0141 | 0.0307 | -0.0590 |
| | (0.0159) | (0.0396) | (0.0404) | (0.0384) | (0.0454) |
| Patient Female x Physician Female | 0.0136 | -0.00704 | 0.0320 | 0.00148 | 0.0867 |
| | (0.0218) | (0.0530) | (0.0562) | (0.0560) | (0.0587) |
| Patient Age | -0.000777* | 0.00291** | 0.00309 | -0.00704* | -0.00216 |
| | (0.000402) | (0.00141) | (0.00525) | (0.00408) | (0.00249) |
| Insurance Type (Medicare) | -0.0481*** | -0.0724 | -0.134 | 0.0435 | -0.0681** |
| | (0.0165) | (0.138) | (0.110) | (0.0438) | (0.0304) |
| Insurance Type (Medicaid) | 0.00843 | 0.190 | -0.0268 | -0.0636 | -0.116 |
| | (0.0470) | (0.120) | (0.148) | (0.137) | (0.132) |
| Insurance Type (Work Comp) | -0.154 | -0.187 | -0.185 | 1.396*** | -0.326 |
| | (0.171) | (0.223) | (0.176) | (0.237) | (0.262) |
| Physician Years of Experience | -0.00251 | -0.00111 | -0.00912 | -0.000916 | -0.00432 |
| | (0.00268) | (0.00697) | (0.00668) | (0.00687) | (0.00689) |
| Constant | 0.449*** | 0.287 | 0.296 | 0.845** | 0.536* |
| | (0.0855) | (0.218) | (0.369) | (0.345) | (0.309) |
| Year Fixed Effects | Yes | Yes | Yes | Yes | Yes |
| Specialty Fixed Effects | Yes | Yes | Yes | Yes | Yes |
| Zip Code Fixed Effects | Yes | Yes | Yes | Yes | Yes |
| Comorbidity Fixed Effects | Yes | Yes | Yes | Yes | Yes |
| Med School Fixed Effects | Yes | Yes | Yes | Yes | Yes |
| Observations | 15,028 | 3,745 | 3,707 | 3,797 | 3,779 |
| R-squared | 0.241 | 0.454 | 0.451 | 0.470 | 0.483 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7: Seizure Age Stratification Regression Results by Quartile

| VARIABLES | (1)<br>Seizure<br>Imaging<br>(All ages) | (2)<br>Seizure<br>Imaging<br>(0 – 17) | (3)<br>Seizure<br>Imaging<br>(18 – 28) | (4)<br>Seizure<br>Imaging<br>(29 - 47) | (5)<br>Seizure<br>Imaging<br>(48+) |
|---|---|---|---|---|---|
| Patient Female | -0.0288*** | -0.0176 | -0.0268 | -0.0261 | -0.0429* |
| | (0.00914) | (0.0204) | (0.0228) | (0.0224) | (0.0223) |
| Physician Female | -0.0170 | -0.0242 | 0.0280 | -0.00215 | 0.000462 |
| | (0.0125) | (0.0246) | (0.0309) | (0.0338) | (0.0318) |
| Patient Female x Physician Female | -0.00636 | 0.0215 | -0.0454 | -0.0309 | 0.00139 |
| | (0.0170) | (0.0325) | (0.0450) | (0.0450) | (0.0436) |
| Patient Age | 0.00240*** | 0.0155*** | 0.000497 | 0.00298* | -0.00415*** |
| | (0.000236) | (0.00148) | (0.00332) | (0.00176) | (0.00118) |
| Insurance Type (Medicare) | -0.0912*** | | -0.520** | 0.0765 | 0.00631 |
| | (0.0305) | | (0.249) | (0.180) | (0.0455) |
| Insurance Type (Medicaid) | -0.0541** | -0.0253 | -0.0355 | -0.0757 | 0.0171 |
| | (0.0260) | (0.0468) | (0.0725) | (0.0726) | (0.0780) |
| Insurance Type (Work Comp) | -0.158*** | | -0.121 | -0.168 | -0.393*** |
| | (0.0522) | | (0.149) | (0.115) | (0.115) |
| Physician Years of Experience | -0.00271 | 0.00208 | -0.00538 | -0.00828 | 0.000379 |
| | (0.00226) | (0.00475) | (0.00566) | (0.00574) | (0.00561) |
| Constant | 0.544*** | 0.223 | 0.626*** | 0.691*** | 0.740*** |
| | (0.0663) | (0.142) | (0.165) | (0.175) | (0.204) |
| Year Fixed Effects | Yes | Yes | Yes | Yes | Yes |
| Specialty Fixed Effects | Yes | Yes | Yes | Yes | Yes |
| Zip Code Fixed Effects | Yes | Yes | Yes | Yes | Yes |
| Comorbidity Fixed Effects | Yes | Yes | Yes | Yes | Yes |
| Med School Fixed Effects | Yes | Yes | Yes | Yes | Yes |
| Observations | 20,414 | 5,106 | 4,995 | 5,020 | 5,293 |
| R-squared | 0.199 | 0.414 | 0.365 | 0.382 | 0.387 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8: Skull Fracture Age Stratification Regression Results by Quartile

| VARIABLES | (1)<br>Fracture Imaging<br>(All ages) | (2)<br>Fracture Imaging<br>(0 – 20) | (3)<br>Fracture Imaging<br>(21 – 31) | (4)<br>Fracture Imaging<br>(32 – 53) | (5)<br>Fracture Imaging<br>(54+) |
|---|---|---|---|---|---|
| Patient Female | -0.0291*** | -0.0148 | -0.0563** | -0.0667*** | -0.00617 |
| | (0.00931) | (0.0206) | (0.0254) | (0.0233) | (0.0240) |
| Physician Female | 0.00887 | 0.0191 | 0.0130 | -0.0507* | 0.0141 |
| | (0.0117) | (0.0240) | (0.0277) | (0.0285) | (0.0358) |
| Patient Female x Physician Female | -0.0108 | -0.0448 | 0.0500 | 0.0211 | -0.0130 |
| | (0.0183) | (0.0389) | (0.0510) | (0.0456) | (0.0469) |
| Patient Age | 0.00246*** | -0.0134*** | -0.000899 | 0.00197 | 0.000223 |
| | (0.000236) | (0.00156) | (0.00318) | (0.00150) | (0.00126) |
| Insurance Type (Medicare) | 0.107*** | -0.724* | -0.219 | -0.217 | 0.163*** |
| | (0.0248) | (0.398) | (0.235) | (0.190) | (0.0378) |
| Insurance Type (Medicaid) | 0.0597* | -0.0507 | -0.0513 | 0.0875 | 0.0590 |
| | (0.0318) | (0.0622) | (0.0980) | (0.0748) | (0.114) |
| Insurance Type (Work Comp) | -0.00896 | -0.206 | -0.0495 | 0.0235 | 0.161* |
| | (0.0318) | (0.205) | (0.0853) | (0.0713) | (0.0854) |
| Physician Years of | -0.00228 | 0.00400 | -0.00369 | -0.00752 | -0.00469 |
| | (0.00225) | (0.00504) | (0.00557) | (0.00542) | (0.00565) |
| Constant | 0.388*** | 0.611*** | 0.604*** | 0.514*** | 0.552*** |
| | (0.0614) | (0.138) | (0.187) | (0.153) | (0.195) |
| Year Fixed Effects | Yes | Yes | Yes | Yes | Yes |
| Specialty Fixed Effects | Yes | Yes | Yes | Yes | Yes |
| Zip Code Fixed Effects | Yes | Yes | Yes | Yes | Yes |
| Comorbidity Fixed Effects | Yes | Yes | Yes | Yes | Yes |
| Med School Fixed Effects | Yes | Yes | Yes | Yes | Yes |
| Observations | 20,643 | 5,466 | 4,903 | 5,162 | 5,112 |
| R-squared | 0.208 | 0.365 | 0.393 | 0.389 | 0.426 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

## 10.2 Summary Statistics

Table 9: Raw Seizure Imaging Rates by Gender

| | Received Imaging – Same Day | Received Imaging – Next Day* | Received Imaging – 2 to 7 days* | Did Not Receive Imaging Within 1 Week | Total |
|---|---|---|---|---|---|
| Female | 4,082 (43.31%) | 436 (4.63%) | 175 (1.86%) | 4,733 (50.21%) | 9,426 |
| Male | 5,129 (46.68%) | 434 (3.95%) | 150 (1.37%) | 5,275 (48.01%) | 10,988 |
| Total | 9,211 | 870 | 325 | 10,008 | 20,414 |

Table 10: Raw Stroke Imaging Rates by Gender

| | Received Imaging – Same Day | Received Imaging – Next Day* | Received Imaging – 2 to 7 days* | Did Not Receive Imaging Within 1 Week | Total |
|---|---|---|---|---|---|
| Female | 2,523 (36.50%) | 721 (10.43%) | 215 (3.11%) | 3,454 (49.96%) | 6,913 |
| Male | 3,416 (42.09%) | 853 (10.51%) | 274 (3.38%) | 3,572 (44.02%) | 8,115 |
| Total | 5,939 | 1,574 | 489 | 7,026 | 15,028 |

Table 11: Raw Skull Fracture Imaging Rates by Gender

| | Received Imaging – Same Day | Received Imaging – Next Day* | Received Imaging – 2 to 7 days* | Did Not Receive Imaging Within 1 Week | Total |
|---|---|---|---|---|---|
| Female | 2,678 (36.99%) | 140 (1.93%) | 16 (0.22%) | 4,405 (60.85%) | 7,239 |
| Male | 5,007 (37.35%) | 284 (2.12%) | 26 (0.19%) | 8,087 (60.33%) | 13,404 |
| Total | 7,685 | 424 | 42 | 12,492 | 20,643 |

*Received Imaging – Next Day does not count patients who received imaging same day. Received Imaging – 2 to 7 Days does not count patients who received imaging same day or next day.

Table 12: Summary Characteristics of Patients Dropped from Sample

| | | First-time Seizure | Acute Ischemic Stroke | Skull Fracture |
|---|---|---|---|---|
| Patient Gender (Count) | Female Patients | 2,499 | 1,802 | 2,404 |
| | Male Patients | 2,722 | 2,017 | 3,837 |
| Physician Gender = F (Rate) | Female Patients | 32.17% | 28.69% | 36.81% |
| | Male Patients | 34.53% | 27.27% | 36.36% |
| Mean Patient Age (Years) | Female Patients | 32.09 | 64.14 | 45.47 |
| | Male Patients | 31.90 | 63.50 | 33.49 |
| Mean Physician Years of Experience | Female Patients | 7.84 | 7.89 | 7.75 |
| | Male Patients | 7.85 | 7.98 | 7.78 |
| Insurance Type | Commercial | 4,489 | 3,004 | 4,860 |
| | Medicare | 165 | 675 | 426 |
| | Medicaid | 438 | 120 | 272 |
| | Workers' Comp | 136 | 19 | 687 |

## 10.3 Supplemental Tables

Table 13: ICD and CPT Codes

| Condition | Codes |
|---|---|
| Non-epileptic seizure (ICD 9 and 10 codes) | R56.9, 780.39 |
| Acute Ischemic Stroke (ICD 9 and 10 codes) | 433.01, 433.11, 433.21, 433.31, 433.81, 433.91, 434.01, 434.11, 434.91, I63.00, I63.011, I63.012, I63.013, I63.019, I63.02, I63.031, I63.032, I63.033, I63.039, I63.09, I63.10, I63.111, I63.112, I63.113, I63.119, I63.12, I63.131, I63.132, I63.133, I63.139, I63.19, I63.20, I63.211, I63.212, I63.213, I63.219, I63.22, I63.231, I63.232, I63.233, I63.239, I63.29, I63.30, I63.311, I63.312, I63.313, I63.319, I63.321, I63.322, I63.323, I63.329, I63.331, I63.332, I63.333, I63.339, I63.341, I63.342, I63.343, I63.349, I63.39, I63.40, I63.411, I63.412, I63.413, I63.419, I63.421, I63.422, I63.423, I63.429, I63.431, I63.432, I63.433, I63.439, I63.441, I63.442, I63.443, I63.449, I63.49, I63.50, I63.511, I63.512, I63.513, I63.519, I63.521, I63.522, I63.523, I63.529, I63.531, I63.532, I63.533, I63.539, I63.541, I63.542, I63.543, I63.549, I63.59, I63.6, I63.8, I63.81, I63.89, I63.9 |

| | |
|---|---|
| Skull Fracture<br>(ICD 9 and 10 codes) | S02.0XXA, S02.101A, S02.102A, S02.109A, S02.110A, S02.111A, S02.112A, S02.113A, S02.118A, S02.119A, S02.11AA, S02.11BA, S02.11CA, S02.11DA, S02.11EA, S02.11FA, S02.11GA, S02.11HA, S02.19XA, S02.2XXA, S02.30XA, S02.31XA, S02.32XA, S02.400A, S02.401A, S02.402A, S02.40AA, S02.40BA, S02.40CA, S02.40DA, S02.40EA, S02.40FA, S02.411A, S02.412A, S02.413A, S02.42XA, S02.600A, S02.601A, S02.602A, S02.609A, S02.610A, S02.611A, S02.612A, S02.620A, S02.621A, S02.622A, S02.630A, S02.631A, S02.632A, S02.640A, S02.641A, S02.642A, S02.650A, S02.651A, S02.652A, S02.66XA, S02.670A, S02.671A, S02.672A, S02.69XA, S02.80XA, S02.81XA, S02.82XA, S02.91XA, S02.92XA, 802.0, 802.4, 802.6, 802.8, 800.00, 801.00, 802.20, 802.21, 802.22, 802.23, 802.24, 802.25, 802.26, 802.27, 802.28, 803.00 |
| Head/Brain CT or MRI<br>(CPT codes) | 70551, 70552, 70553, 70554, 70555, 70450, 70460, 70470 |
| ER Encounter<br>(CPT Codes) | 99281, 99282, 99283, 99284, 99285 |

Table 14: Comorbidities*

| | | | |
|---|---|---|---|
| Myocardial infarction | Chronic pulmonary disease | Hemiplegia or paraplegia | Coronary artery disease |
| Congestive heart failure | Rheumatic disease | Renal disease | Hypertension |
| Peripheral vascular disease | Mild liver disease | Any malignancy | AIDS/HIV |
| Cerebrovascular disease | Diabetes with chronic complication | Liver disease | Metastatic solid tumor |
| Dementia | Diabetes without chronic complication | Peptic ulcer disease | Asthma |

*List of comorbidities is based on diagnoses included in the Charlson Comorbidity index, with the addition of common chronic conditions not included in the Charlson index (asthma, hypertension, coronary artery disease)