How are Patient Order and Shift Timing Associated With Imaging Choices in the Emergency Department? Evidence From Niagara Health Administrative Data

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Study objective: We assessed whether the timing and order of patients over emergency shifts are associated with receiving diagnostic imaging in the emergency department and characterized whether changes in imaging are associated with changes in patients returning to the ED.

Methods: In this retrospective study, we used multivariate and instrumental variable regressions to examine how the timing and order of patients are associated with the use of diagnostic imaging. Outcomes include whether a patient receives a radiograph, a computed tomography (CT) scan, an ultrasound, and 7-day bouncebacks to the ED. The variables of interest are time and order during a physician's shift in which a patient is seen.

Results: A total of 841,683 ED visits were examined from an administrative database of all ED visits to Niagara Health. Relative to the first patient, the probability of receiving a radiograph, CT, and ultrasound decreases by 6.4%, 9.1%, and 3.8% if a patient is the 15th patient seen during a shift. Relative to the first minute, the probability of receiving a radiograph, CT, or ultrasound increases by 1.9%, 2.7%, and 1.1% if a patient is seen in the 180th minute. Seven-day bounceback rates are not consistently associated with patient order or timing in a shift and imaging orders.

Conclusion: Imaging in the ED is associated with shift length and especially patient order, suggesting that physicians make different imaging decisions over the course of their shifts. Additional imaging does not translate into reductions in subsequent bouncebacks to the hospital. [Ann Emerg Med. 2022;■:1-9.]

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INTRODUCTION

The use of investigative imaging during emergency department visits has increased over the last decade, resulting in increased health care costs.[1,2] In addition, unnecessary imaging exposes patients to radiation and longer wait times, thus reducing the quality of care provided.[3,4] Campaigns to change practice patterns, such as Choosing Wisely, are a backlash against this overuse, especially for low-risk patient presentations.[5] It is the subject of academic and professional discourse, such as Preventing Overdiagnosis, Right Care Alliance, and the Academic Emergency Medicine 2015 consensus conference.[6-8] Overuse has also been important in how policies, such as the Affordable Care Act, are designed to financially penalize medically unnecessary imaging studies.[9] However, the gatekeepers for ordering imaging are emergency physicians whose diagnostic decisions may be subject to cognitive biases. If cognitive biases affect imaging choices, more nuanced interventions to reduce imaging use may target these biases directly.

These cognitive biases become evident because of the chaotic nature of emergency medicine. Emergency physicians are the first contact for a significant proportion of patients and may make hundreds of decisions during their shift.[2] This has been hypothesized to cause decision fatigue, which is defined as the loss of self-control that follows the act of making many decisions.[10] Consequently, the same patient who is seen at the beginning of a physician's shift may receive different imaging when seen at the end of the shift. Decision fatigue has been observed in primary care physicians who prescribe more antibiotics and opioids near the end of their day in clinic and in surgeons

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Editor's Capsule Summary

What is already known on this topic

Imaging ordering in the emergency department (ED) is common and variable, the latter sometimes unrelated to patient features.

What question this study addressed

Does the order and the relative time within an ED care shift affect the frequency of ordering imaging and the occurrence of later return care?

What this study adds to our knowledge

As the order within and the time of an ED shift progresses, the probability of ordering diagnostic imaging increases without impacting later return for care.

How this is relevant to clinical practice

This important potential relationship may help guide better strategies to improve imaging decisions.

who are less inclined to proceed with surgical management near the end of their day at clinic.[11-13] In the ED setting, we are only aware of 1 study that shows mixed results in the probability of receiving an imaging test based on the timing of the patient's visit.[14]

However, this literature suffers from 2 limitations. First, it has focused on shift timing instead of the timing and volume of patients. In some cases, such as clinic work, this is natural because the number of patients that a physician examines is set by a scheduler. However, this is not the case in the ED, where physicians may see a variable number of patients depending on how busy the shift is. Where a patient is in the timing of a physician's shift may have different impacts on decisions than where a patient is in the order of the shift. A unique contribution of this article is that our data provide enough power to tease apart these 2 associations.

Second, this literature has largely focused on decision fatigue that results in negative outcomes, such as over-prescribing antibiotics or opioids. However, it may be the case that the practice that comes with seeing many patients may hone diagnostic decisionmaking and produce more optimal outcomes over the course of a physician's shift. For example, a physician may be more uncertain at the beginning of their shift and over-order testing but become more confident over time in ordering an appropriate level of testing. Thus, we deviated from the traditional definition of decision fatigue and defined it as whether decisions over a shift are inconsistent. We defined 2 subcategories of decision fatigue. First, fatiguing down is a process where inconsistent decisions result in worse outcomes—as in this case, bouncebacks to the ED. Second, we defined tuning up as inconsistent decisions that result in improved outcomes over a shift. Understanding whether a physician is fatiguing down or tuning up is important because the interventions that target these 2 entities will be different. Our study adds to the literature in investigating this novel mechanism that explains why emergency physicians may change their imaging decisions over a shift.

In this study, we examined how the timing and order of patients over emergency shifts are associated with receiving diagnostic imaging in the ED. We further characterized this association with respect to fatiguing down or tuning up by examining whether increasing imaging use is associated with bouncebacks to the ED.

MATERIALS AND METHODS

This study was deemed exempt from review by the Hamilton Integrated Research Ethics Board (HiREB #13348).

Institutional Background

The setting of this research is the Niagara Health System ED network consisting of 3 ED sites in the southeastern portion of Ontario, Canada. This region is home to 500,000 people, and Niagara Health sites see more than 200,000 patient visits annually. These sites are in St. Catharines, Niagara Falls, and Welland and are attached to hospitals. They can access 24-hour laboratory services and advanced diagnostic investigations, such as computed tomography (CT) and magnetic resonance imaging. In addition, there are 2 urgent cares in the Niagara Health System, which we did not examine in this study. A shift schedule documenting the timing of various shifts at all sites in the system is contained in Figure E1 (available at http://www.annemergmed.com/).

Triaging at these EDs occurs exclusively by nurses before being seen by physicians and is done in order of patient presentation to the ED. There are exceptions for critically ill patients and ambulance-transferred patients, who are triaged in a queue separate from that for walk-in patients. Basic testing, including radiography, can be ordered at triage before physicians see a patient but requires a verbal order from the physician. A triage score is assigned to each patient on the basis of the complaint, demographics, and vital signs to determine how quickly a patient should be seen. The timing and order of being seen by a physician can be altered by the triage nurse by streaming patients toward acute and "see-and-treat" sections of the ED or by directly

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flagging a patient for a physician. Patients are otherwise placed in a chart order for physicians to see by the time of arrival to the ED. It is routine for finishing physicians to hand over patients to colleagues who are starting their shifts to complete investigations. Physicians generally work at all sites in the system.

Medical care in Ontario is publicly funded by the government. There are no point-of-care costs for any medical care delivered through the ED, including diagnostics, treatments, and physician assessments.

Data

ED visits are from an administrative dataset collected by Niagara Health. This consists of all patient visits to 1 of these 3 ED sites from April 2013 to March 2019. This comprises 841,683 visits in regressions without covariates and 712,750 visits in regressions with covariates (Figure E2). Visit information includes the complaints of the patient, their demographics, the triage, examination, and discharge timing. We tracked patients over time and constructed variables on whether and when a patient returned to an ED in the Niagara Health System.

Variables of Interest

We examined 2 variables of interest that may be associated with a change in imaging outcomes during a shift. First, using the information on physician examination timing, we ordered patients during a shift to assess how this is associated with changes in our outcomes of interest. We censored this outcome at 40 patients because it is rare for a physician to see more patients during a shift. Second, using the same information on physician examination timing, we binned patients into 15-minute blocks on the basis of the time they were seen. For example, individuals examined during the 1st to 15th minute of a physician's shift were given a value of 0, whereas an individual examined during the 15th to 30th minute of a shift was given a value of 15 minutes. Similarly, because it is rare for a physician to see patients for more than 16 hours straight, we censored this outcome at 960 minutes.

Outcome Variables

We were interested in 2 outcomes; the first was whether a patient received diagnostic imaging, and the second was whether a patient has an adverse outcome after their visit. For the former, we evaluated whether patients received a radiograph, CT scan, or ultrasound during their visit. For the latter, we examined visits that resulted in a bounceback to an ED. We compared persons who received a test at a given time or order to those who did not. We considered that a bounceback occurred when the outcome of a visit was a subsequent ED follow-up within 7 days. We considered an alternative bounceback outcome where a follow-up occurred and resulted in an admission to the hospital within 7 days.

Statistical Strategy

We used multivariate regression analysis to estimate the relationship between patient order and patient timing and the outcomes of imaging occurrence and bouncebacks. We created dummy variables for our variables of interest to estimate the individual effect of patient order and examination time and its effects on imaging. For our primary results, we demonstrated results without covariates and then showed results adjusted for covariates. We included the age, sex, triage score, ambulance use, and complaint fixed effects of the patient as covariates in our regressions because this information is contained on the chart a physician sees and, thus, may be correlated with physician ordering and timing. In addition, we controlled for hour of the day, day of the week, month, year, and site fixed effects as covariates that influence patient demand for care. We also included physician fixed effects and fixed effects for the number of patients a physician sees as covariates that may influence the test ordering rates of the physician.

We then examined the interaction between receiving diagnostic imaging and timing during a shift and how it is associated with bouncebacks for persons who received a test and those who do not. Finally, we took the same patient order and timing dummies and interacted them with a dummy variable for imaging to assess whether the patient was admitted or returned to the ED. All standard errors were clustered at the physician-ED-day of week level. The details of these regressions are contained in Appendix B Appendix E1 (available at http://www.annemergmed.com/).

Instrumental Variable Strategy

To establish a causal relationship between patient order, patient timing, and whether a diagnostic test or bounceback occurred, the assumption must hold that unobserved patient and physician characteristics are not driving outcomes after controlling for observable covariates. In other words, the error term in our regressions must be uncorrelated with our variables of interest, conditional on our covariates, as is the case in a natural experiment. However, we think this is unlikely to be the case because physicians are likely to choose types of patients depending on where they are in their shift timing.[15] For example, as a physician gets closer to the end of their shift, they may substitute away from patients who are likely to require

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more involved investigations and leave these for a physician coming on to work. This causes selection because the finishing physician chooses patients who are less likely to need investigations, and the physician starting will have to see a larger number of patients who likely require investigations.

To assess causal effects, we employed an instrumental variable that attempts to approximate a natural experiment.[16] The omitted variable that the instrumental variable circumvents is the unobserved health status of the patient that would cause a physician to change the timing and order of a patient and the probability of obtaining imaging for the patient. For the instrumental variable to be causal, it must affect our outcomes of interest but only through shift order and timing of a patient. We used the triage timing and order of the patient relative to the order and time of the physician's first patient as an instrumental variable for the order and timing a patient is seen by the physician (Figure E3). The physician cannot influence the triage timing because this depends on when the patient arrives at the ED. However, the triage order and timing affect physician assessment order and timing because of the convention of seeing patients who have waited for the longest or who are next in line. The exception is ambulance-transported patients, who may jump the triage queue, which is why we controlled for this in regressions. We estimated the probability of a patient receiving a radiograph, CT, or ultrasound on the basis of the instrumented timing and order of a patient being seen by the physician and then estimated the effect of this change in imaging probability on a patient bouncing back. The details of this instrumental variable strategy are contained in Appendix E1, and we provided ordinary least square estimates for comparison.

RESULTS

Baseline Probabilities of Imaging

We observed 841,682 visits to EDs in the Niagara Health System collected between April 2013 and March 2019. The probability of a radiograph, CT scan, or ultrasound occurring during a visit was 36.1%, 14.6%, and 5.6%, respectively. In addition, the probability of bouncebacks within 7 days was 10.6%, and the probability of bounceback with admission in 7 days was 1% (Table E1).

Probability of Diagnostic Imaging Associated With Timing and Patient Order in a Physician's Shift

Figures 1 and 2 demonstrate associations between the probability of receiving imaging and the order and timing that a patient is seen during a physician's shift. The top panel of each figure displays raw associations, and the bottom panel displays regression results controlling for covariates. These figures display point estimates with 95% confidence intervals (CIs). Relative to the first 15 minutes, the probability of receiving diagnostic imaging increases by 1.9% (95% CI 0.0069 to 0.0306) for radiographs, by 2.7% (95% CI 0.0165 to 0.0366) for CT scans, and by 1.1% (95% CI 0.0045 to 0.0193) for ultrasounds if a patient is seen in the 180th minute of a physician's shift after controlling for patient order. Relative to the first patient, the probability of receiving a radiograph, CT scan, or ultrasound decreased by 6.4% (95% CI −0.0796 to −0.0480), 9.1% (95% CI −0.1050 to −0.0768), and 3.8% (95% CI −0.0485 to −0.0283), respectively, if a patient is the 15th patient seen during a shift after controlling for covariates. In both associations, changes in imaging probability occurred rapidly after the first 15 minutes or first several patients and then plateaued.

Probability of Testing and Bouncebacks to ED

Figure 3 demonstrates the probability of return to the hospital and patient order for patients receiving imaging and those not receiving imaging. Relative to the first 15 minutes, being seen in the 180th minute does not consistently change the probability of bouncebacks in persons who receive tests or persons who do not receive tests (Figure 3), except in the case of radiographs and ED representations. Figure 4 also demonstrates no change in the probability of bouncebacks with admission based on order and whether a patient receives imaging, except in the case of radiographs and ED representations. This suggests that individuals who did not receive testing are not returning to the ED at higher rates, except in the cases of radiographs. Patients who receive radiographs and are seen later in the shift timing are more likely to bounceback, whereas patients who are seen later in order are less likely to bounceback relative to patients who do not receive radiographs.

Instrumental Variable Results

Table E2 demonstrates the first stage of our instrumental variables. When the triage order of a patient increases by one, the order that the patient is seen by the physician increases by 0.13 (95% CI 0.111 to 0.149), and the timing that a patient is seen decreases by 1.23 minutes (95% CI −1.400 to −1.071). When the triage minute of a patient increases by one, the order that the patient is seen by the physician increases by 0.0102 (95% CI 0.009 to 0.111), and the timing that a patient is seen increases by 0.719 minutes (95% CI 0.698 to 0.740).

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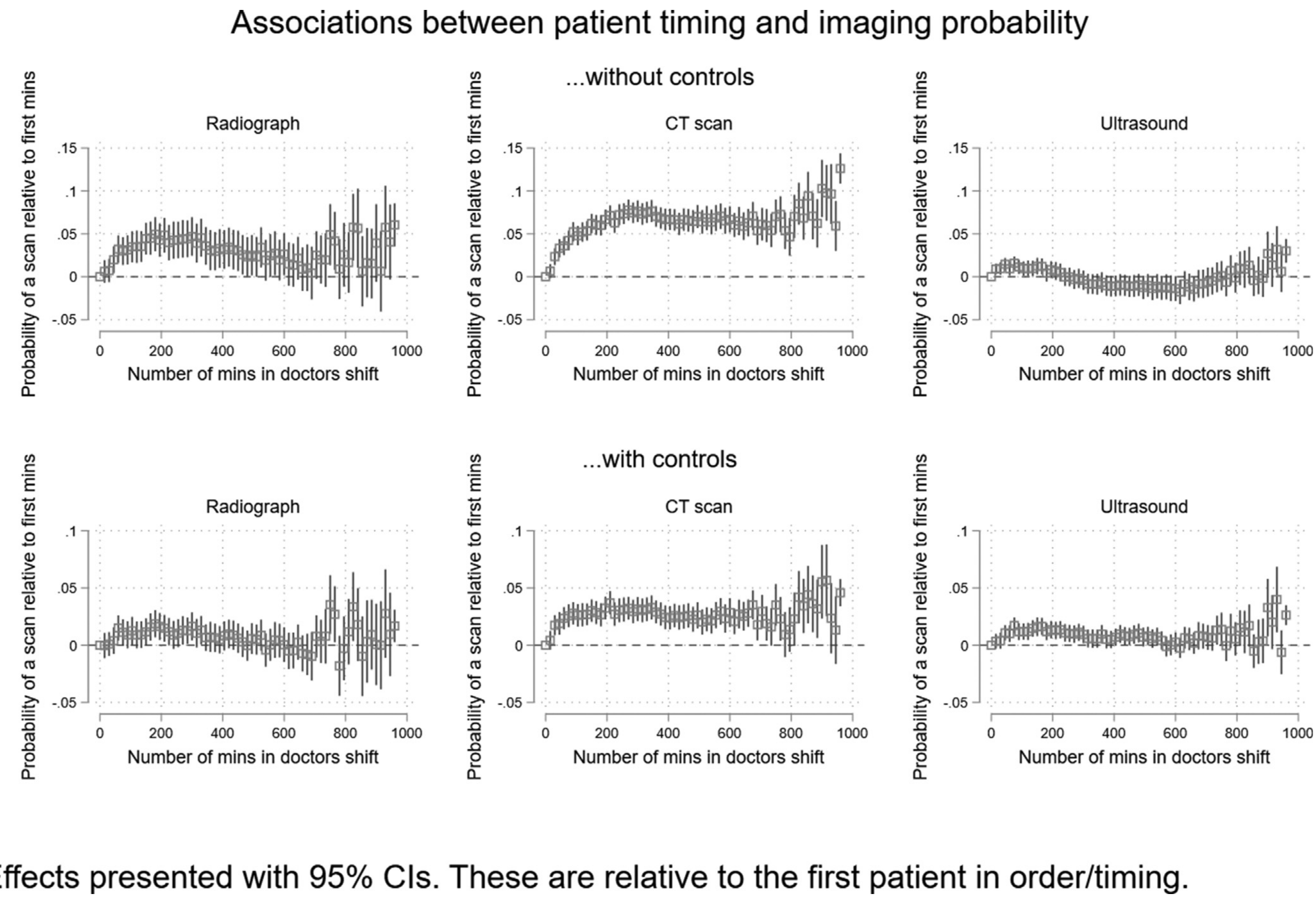

Figure 1. Probability of tests ordered (radiograph, CT scan, ultrasound) based on time of presentation in a physician's shift. Point estimates with 95% CIs are displayed.

Table E3 demonstrates the results of our second stage and the impacts of the change in imaging probability on bouncing back. Ordinary least square results are like our graphical results and show a declining relationship between patient order and imaging probability. For example, for every increase in order that a patient is seen, the probability of receiving radiograph declines by 0.12% (95% CI −0.0017 to −0.0008). There is no significant relationship between imaging probability and minutes that a patient is seen in a physician's shift in our ordinary least square regressions. Increasing the probability of receiving a CT scan or ultrasound is associated with an increase in the probability of bounceback with admission within 7 days in our ordinary least square regressions; for example, a 1% increase in the probability of receiving a CT scan increases the probability of bounceback with admission by almost 4% (95% CI 0.0080 to 0.0819).

However, our second stage instrumental variable results differ from our ordinary least square results. Associations between patient order and imaging are all significant and much more negative. For example, an increase in the order of being seen by 1 reduces the probability of the patient receiving a radiograph by 0.4% (95% CI −0.00567 to −0.0026). This means that the probability of receiving radiograph decreases by 6% if a patient is the 15th patient seen by a physician relative to their first patient. Associations between minutes of being seen and imaging are positive for radiographs and ultrasounds. For example, a 1-minute increase in the time of being seen increases the probability of a patient receiving a radiograph by 0.007% (95% CI 0.00003 to 0.00008). By comparison, this suggests that the probability of receiving a radiograph decreases by 1.26% if a patient is seen in the 180th minute seen by a physician relative to the first minute. However, the increase in probability caused by changes in a minute of being seen or the order of being seen does not translate into changes in the probability of bouncing back.

LIMITATIONS

The limitations of this study can be broken into 4 major issues. The first is whether we are measuring correct outcomes. We defined adverse outcomes as a bounceback to the ED because it is a concrete outcome. However, we

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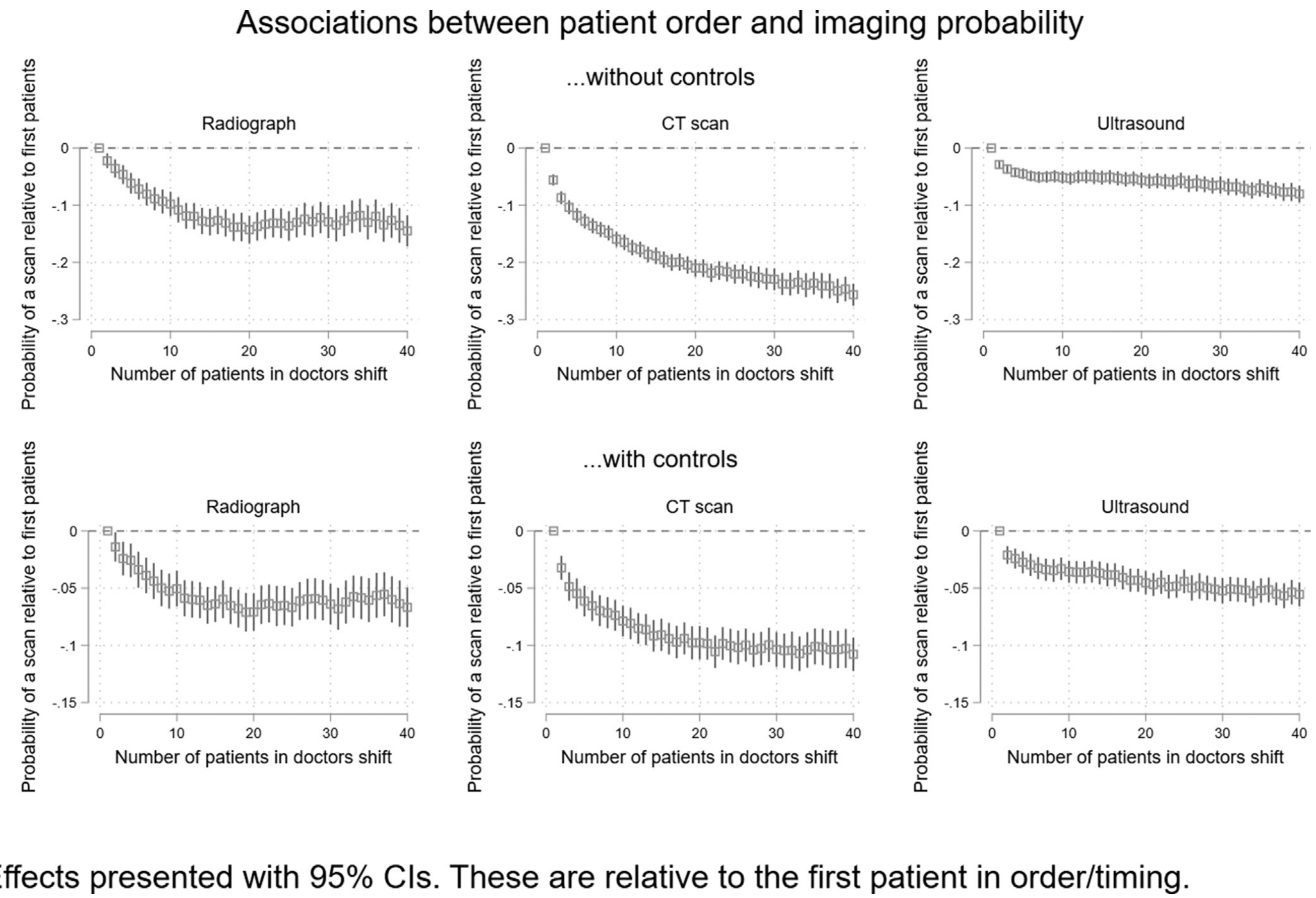

Figure 2. Probability of tests ordered (radiograph, CT scan, ultrasound) based on patient order of presentation in a physician's shift. Point estimates with 95% CIs are displayed.

acknowledge that this is not the only outcome that may reflect adverse effects. For example, patient satisfaction and other patient-oriented outcomes are variables we could not observe and may measurably change for better or worse because of patients receiving imaging. Moreover, we did not observe imaging results; hence, we could not determine the true clinical appropriateness of the imaging. In the ED, certain tests must be performed in low-probability clinical scenarios—for example, ordering a head CT scan in a patient with minor head trauma but on anticoagulation therapy. Similarly, a more concrete outcome might be deaths; however, we could not observe deaths in the community or hospital, and there are relatively few deaths within the EDs in Niagara.

Second, our goal in this study was to assess whether decision fatigue exists in the ED, especially regarding imaging choices. To do so, we necessarily relied on observational data, which means that estimated effects might be biased because of unobserved covariates that influence imaging and patient selection. For example, we did not observe covariates linked to physician experience, which may also play a role in patient outcomes, selection, and imaging choices. Our instrumental variable strategy attempted to circumvent this; if triaging occurs in order of patient presentation to the ED, orthogonal to unobserved health status, then the variation in the order and timing of a patient being seen by the physician caused by triage timing and order should approximate a natural experiment. Whether this is believable hinges on if triage timing and triage order only affect imaging choices through the timing and order of the patient being seen by the physician. If this exclusion restriction does not hold, our instrumental variables are not causal.

Third, although we have attempted to provide evidence on the mechanisms driving these effects, these must also be interpreted cautiously.[17,18] We deliberately departed from the previous definitions of decision fatigue to try and explain a novel result that is inconsistent with previous definitions of decision fatigue; the probability of a patient receiving imaging changes over the course of the shift, and this does not result in worse outcomes. These results are consistent with the process of decision fatigue and tuning up; however, one can

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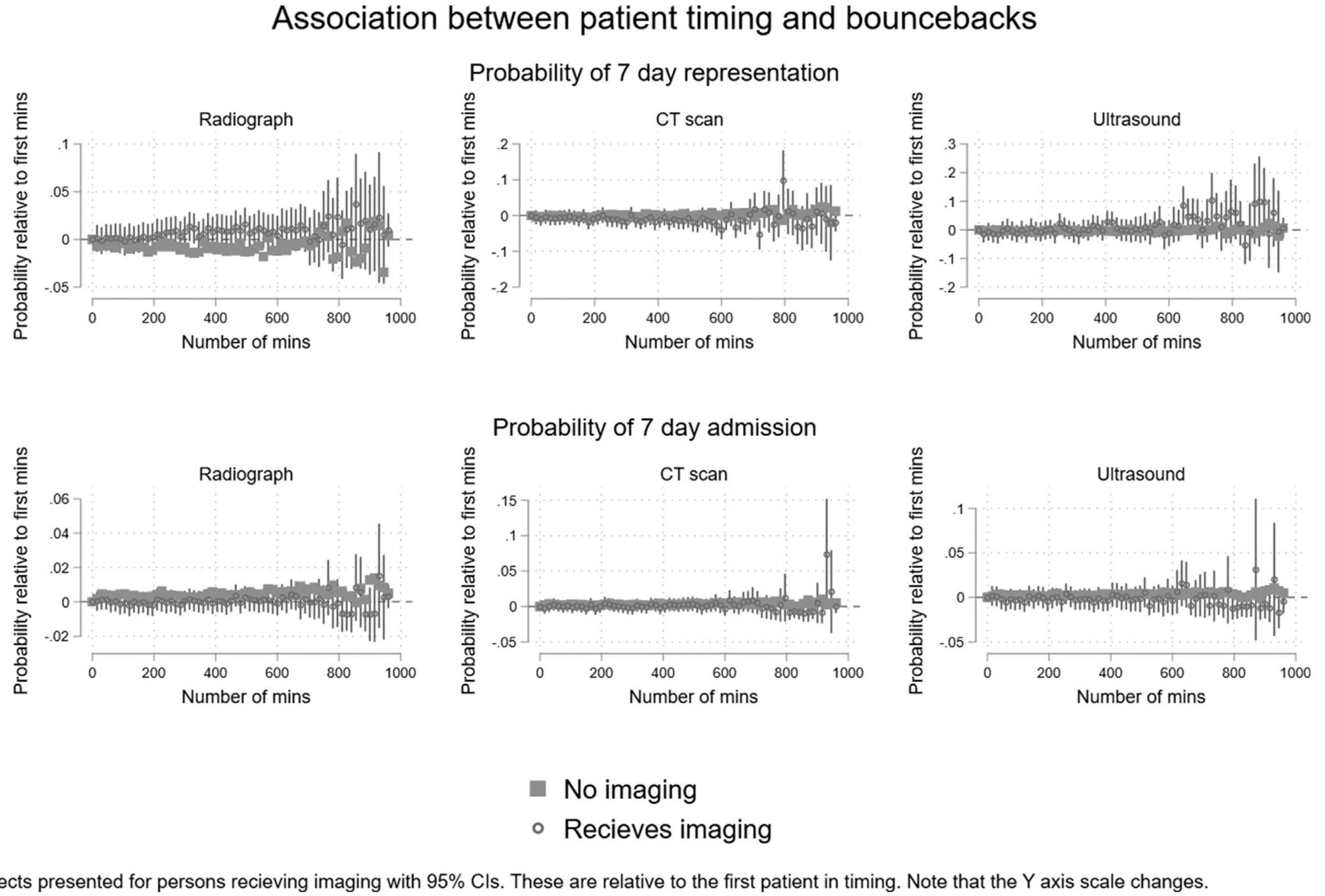

Figure 3. Probability of bouncebacks associated with imaging and the time of presentation in a physician's shift. Point estimates with 95% CIs are displayed for patients receiving imaging.

think of various processes that might lead to an observably similar outcome but require different interventions to correct. For example, a physician that collects a complete history or physical and does not order tests would have different policy implications than a mechanism where the physician collects the same information but chooses to test differently because of tuning up. Unfortunately, we cannot directly observe these mechanisms.

Finally, these results also must be interpreted cautiously for their external validity. Shift structure in the EDs in Niagara may be unique relative to other health systems. For example, hand-off culture at other systems may mean different incentives for ordering tests at the end of the shift. The Niagara region has also been noted for its lack of primary care options which may push people to use EDs for low acuity issues or delayed presentations. In addition, Canadian medical systems' payment systems may differ from those in other medical systems, producing different incentives to test during a shift. These could all affect the magnitude and direction of our estimated effects.

DISCUSSION

We show 3 major results in this paper. First, there are large associations between the probability of receiving imaging and the order and timing that a patient is seen in the ED. This could be consistent with an explanation of decision fatigue or patient selection; however, our instrumental variable results are similar to our main results and suggest changing decisions as culprits. This is consistent with findings in previous literature.[11,12,14]

Second, these changing associations are largely driven by order of patients rather than the timing of patients. A patient seen as the 15th patient is far less likely to receive a test than the first patient, whereas a patient seen in the 180th minute is only marginally more likely to receive a test relative to a patient seen in the first minute. This result fits into a recent literature's on-duty hour restrictions that have become of interest to the internal medicine community. Much of that literature finds no changes in patient outcomes with mandatory reductions in duty hours, suggesting that it is not the length of work that is a major factor in patient outcomes.[19,20] At least 1 study in an

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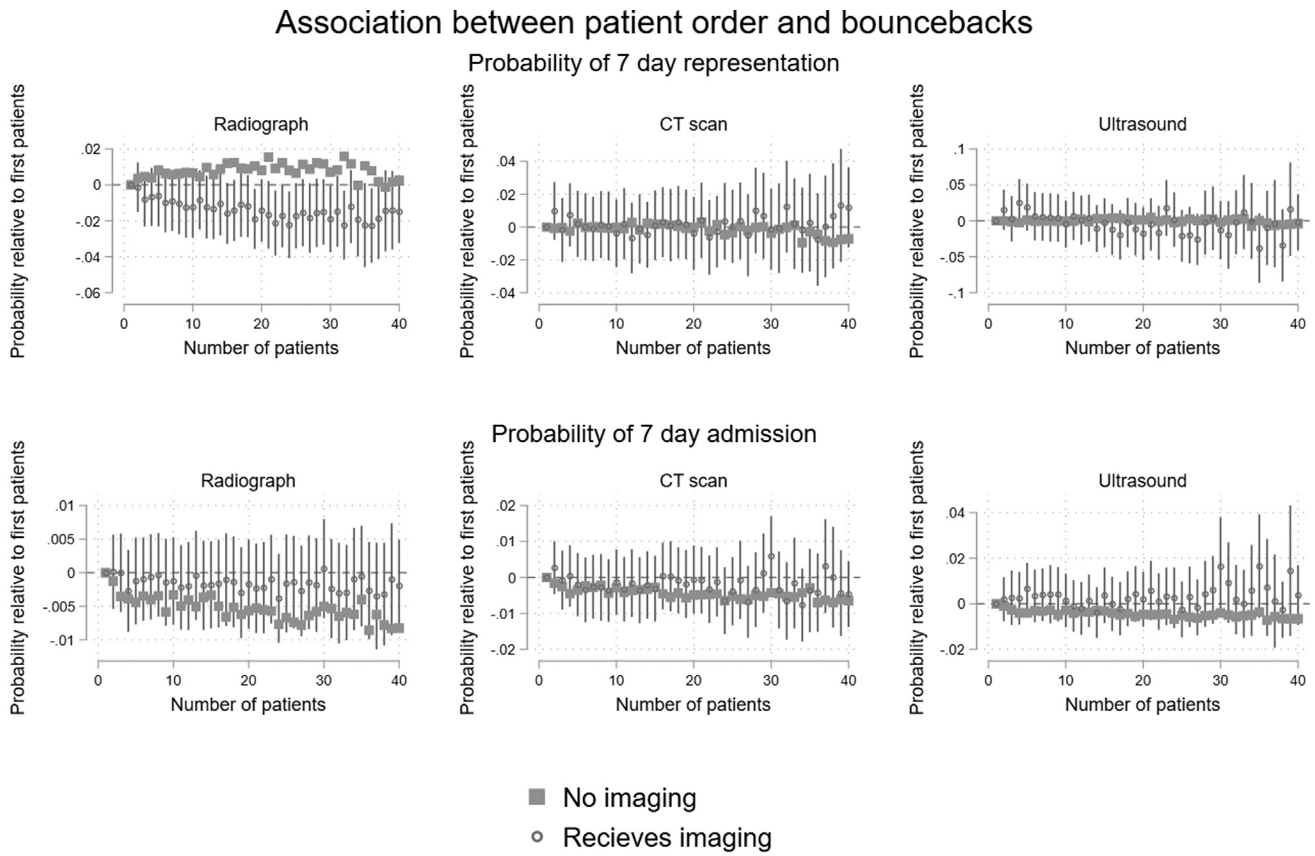

Effects for persons recieving imaging presented with 95% CIs. These are relative to the first patient in order. Note that the Y axis scale changes.

Figure 4. Probability of bouncebacks associated with imaging and the order of presentation in a physician's shift. Point estimates with 95% CIs are displayed for patients receiving imaging.

ICU showed that, after controlling for patient load, there were no increases in medical errors with longer shifts.[18] Our result is consistent with those in that when a person is seen during a shift has a small effect on imaging probability relative to patient order. This suggests that it is how busy the shift is, not how long the shift is, that drives changes in decisions.

Third, the changes in decisions that we documented could be indicative of fatiguing down or tuning up, and we found evidence for both processes occurring in our data. Because patients were seen later in the order, they were significantly less likely to receive imaging; however, bounceback rates over the next 7 days were not affected, except for radiograph, where bouncebacks decreased for patients receiving imaging. This suggests a tuning up effect in which physicians seem to be reducing the number of tests they ordered but at no cost to increased bouncebacks or decreases in bouncebacks. This contrasts with previous literature where physicians made worse decisions over the course of a day or shift. However, as the time a patient is seen in a shift increases, the patient is more likely to receive imaging. This did not result in any change in bouncebacks, suggesting that these tests were over-ordered, except in the case of radiograph, where bouncebacks increased in timing. This indicates that there may be some element of fatigue as shift length increases; this latter effect is smaller in magnitude and less consistent relative to the effects we found with respect to patient ordering.

In summary, we demonstrate that over the course of a shift, emergency physicians use diagnostic imaging with changing probability over the order of patients and timing of a shift. We found that tuning up occurs in patient order, whereas fatiguing down occurs in patient time; however, the former effect is much larger in magnitude. Although previous studies have shown decision fatigue as a factor, our main results suggest tuning up effect over an emergency physician's shift as the initial higher probability of receiving imaging with increasing patient order does not reduce subsequent bouncebacks to the hospital. Physicians should be aware of how these possible cognitive biases affect their imaging choices when engaging in clinical work.

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