



## ORIGINAL CONTRIBUTION

# Association between advanced image ordered in the emergency department on subsequent imaging for abdominal pain patients

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## Abstract

**Background:** Abdominal pain is associated with high rates of emergency department (ED) imaging utilization and revisits. While imaging often improves diagnosis, a better understanding is needed on when the decision to image is justified and how it influences subsequent resource utilization and outcomes for patients in the ED presenting with abdominal pain. We evaluated the association between advanced ED imaging on subsequent outpatient imaging and on revisits among abdominal pain patients discharged from the ED.

**Methods:** A retrospective, observational study was conducted using electronic health record data from an academic ED in the U.S. Midwest. A sample of Medicare patients with a chief complaint of abdominal pain from January 2013 to December 2016 following ED evaluation were included in the analysis. Logistic regression was used to estimate associations between receiving advanced imaging in the ED and subsequent outpatient imaging within 7-, 14-, and 28-day windows after discharge, and 30-day revisit rates to the study ED and to any ED.

**Results:** Of the 1385 ED visits with abdominal pain chief complaint and discharged home from the ED, individuals who were *not* imaged in the ED had significantly higher adjusted odds of being imaged outside the ED within 7 days (adjusted odds ratio [aOR] 6.65, 95% confidence interval [CI] 3.96–11.17,  $p < 0.001$ ), 14 days (aOR 4.69, 95% CI 3.11–7.07,  $p < 0.001$ ), and 28 days (aOR 3.1, 95% CI 2.25–4.27,  $p < 0.001$ ) of being discharged and had a significantly higher adjusted odds of revisiting the study ED (aOR 1.65, 95% CI 1.29–2.12,  $p < 0.001$ ) and revisiting any ED (aOR 1.47, 95% CI 1.16–1.86,  $p = 0.001$ ) within 30 days of being discharged.

**Conclusions:** Abdominal imaging in the ED was associated with significantly lower imaging utilization after discharge and 30-day revisit rates, suggesting that imaging in the ED may replace downstream outpatient imaging.

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## INTRODUCTION

Americans rely on the emergency department (ED) for acute, unscheduled care. Primary physicians increasingly refer patients to the ED for acute issues as opposed to scheduling office visits; ED physicians are now responsible for 28% of all acute care visits.<sup>1</sup> Abdominal pain prompts more ED visits than any other chief complaint, representing 8.8% of visits in the Centers for Disease Control and Prevention's National Hospital Ambulatory Medical Care Survey, responsible for over 12 million annual ED visits,<sup>2</sup> and the number of visits for abdominal pain is growing both absolutely and proportionally to other chief complaints.<sup>3</sup> Given the broad differential diagnosis for these patients, they are subject to complex evaluations including advanced imaging such as computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound. These visits are associated with high rates of ED imaging compared to other complaints with rates ranging from 25% to more than 40%<sup>4</sup> and high rates of return visits.<sup>4-6</sup>

ED visits and imaging are commonly viewed as inefficient or overutilized, with policymakers and the press focusing on reducing "unnecessary" ED visits or imaging studies.<sup>7</sup> Additionally, return visits to the ED are being scrutinized as a measure of lower quality and more costly care.<sup>8,9</sup> A better understanding is needed to fully characterize the effects of imaging decisions made in the ED. We examined associations between advanced imaging (i.e., CT, MRI, and ultrasound) and subsequent care trajectories and resource utilization. We hypothesized that advanced imaging in the ED is associated with decreased rates of subsequent imaging in outpatient settings and ED revisits for patients with abdominal pain that are discharged from the ED.

## METHODS

### Study setting and population

We analyzed electronic health record (EHR) data from an academic tertiary care ED in the U.S. Midwest with over 60,000 yearly visits between January 1, 2013, and December 31, 2016. Data were restricted to ED visits where patients had Medicare coverage during the month(s) of the index ED visit (admit and discharge month, if different) and had the opportunity for 90 days of postdischarge follow-up Medicare coverage, including patients who died within the 90-day time frame but otherwise had coverage. We focused on adult patients (18 years or older) who were discharged from the ED and had abdominal pain as their chief complaint and an Emergency Severity Index (ESI) level of 2 and 3 ( $n = 2894$ ). Records with the following missing variables were excluded: ESI ( $n < 11$ ), income (at census block group level based on geocoded address) ( $n = 224$ ), heart rate ( $n < 11$ ), blood pressure ( $n = 107$ ), respiration ( $n = 42$ ), and temperature ( $n = 34$ ). After records with missing variables were removed, a total of 2509 records remained. Out of these 2509 records, 1385 corresponded to discharges from the ED and were thus used

for analysis. Among the final 1385 records used for analysis, some individuals died during the study period ( $n < 10$ ), but upon removing them from the sample, we arrived at similar findings; these findings were thus omitted for brevity.

ED visit information included baseline demographic, socioeconomic, and clinical comorbidity variables. Sex was binary (female/male). Race/ethnicity was categorized based on whether an individual was identified as White, Black/African American, Hispanic, American Indian, or Asian/Pacific Islander. Additional variables were captured at the start of the ED visit that reflect underlying health needs (ESI level, temperature, blood pressure, respiratory rate, and heart rate).

In addition to the variables above, we also explored how the operational context of the ED may change the associations of interest. To this end, we included the following operational variables: congestion (the ED census at the time of arrival including everyone in the ED, regardless of who they are, where they are in the ED, or their treatment pathway) and physician workload (the ratio of ED census at the time of arrival divided by the number of providers in the ED at the time of arrival). Congestion and physician workload were transformed into categorical variables representing tertiles, with the lowest (highest) tertile corresponding to those days with the lowest (highest) levels of congestion or workload.

### Key outcomes measures

Our primary outcomes were 7-, 14-, and 28-day outpatient imaging; 30-day revisits to the study ED; and 30-day revisits to any ED representing, respectively, binary variables indicating whether an individual had an outpatient image outside the ED within 7, 14, and 28 days after being discharged from the study ED at their initial index visit; whether the patient returned to the study ED (based on EHR) after being discharged at their initial index visit; and whether the patient visited any ED (based on claims) within 30 days after being discharged at their initial index visit. Binary variables indicating whether an individual had an outpatient image outside the ED within 7, 14, and 28 days after discharge and whether the patient visited any ED within 30 days after discharge were obtained from claims, whereas the binary variable indicating return visits to the study ED within 30 days was obtained from the EHR.

### Data analysis

We conducted direct logistic regression to evaluate associations between receiving advanced ED imaging and subsequent advanced outpatient imaging and revisits for abdominal pain patients discharged home from the ED. Logistic regression models were fit to the 1385 records of abdominal patients who met inclusion criteria for analysis. Since a patient might contribute multiple records to the sample, which can lead to correlated visits, the logistic regression analysis was performed using the generalized estimating equation

(GEE) framework.<sup>10</sup> Correlated visits were accounted for in the GEE framework by specifying an independence working correlation structure, which assumes observations over time are independent.

We report both the unadjusted and adjusted odds ratios (aORs) with corresponding 95% confidence intervals (CIs). For the adjusted estimates, baseline variables and variables reflecting underlying health needs were included in the logistic regression model. These variables were selected prior to performing any analyses based on the clinical judgment of the emergency physician coauthor. We also repeated analyses stratified by ED congestion level and by ED workload level (e.g., low, middle, and high congestion tertile) to determine whether the association between imaging in the ED and subsequent outpatient imaging is affected by these operational variables.

Additional analyses were performed to evaluate robustness of findings to several modeling and data choices. First, our analysis was repeated but with Medicare patients that were less than 65 years old removed and is reported in the online supplement (Table S1). Second, since a patient might contribute multiple records to the sample, we repeated our analysis using only the first visit of each patient and reported these results in the online supplement (Table S2). Third, checks on model fit and the robustness were performed, and our findings are summarized in the online supplement. Results from eliminating influential observations and outliers yielded similar estimates when using all observations and are summarized in Table S4 of the online supplement. Since estimates were similar between models, these observations were included in the main analysis.

All statistical analyses were performed with RStudio version 1.3.1073. Given our fixed sample size of 1385 patients who met our inclusion criteria, we estimated minimally detectable effect sizes at  $\alpha = 0.05$  using the logistic regression option in G\*Power.<sup>11</sup> Approximately 54% of our sample is imaged in the ED, and 19% of individuals not imaged in the ED receive imaging outside the ED in 7 days; based on these estimates, we achieved 80% power to detect odds ratios of at least 1.5 for our outcomes. Given the estimated higher percentage of individuals imaged at 14 and 30 days, we expect to have sufficient statistical power for these additional outcomes.

## RESULTS

Baseline characteristics of our sample are summarized in Table 1. Briefly, the sample was predominantly white (86%) and female (65%) and had an average age of 60 years. Most arrived at the ED by “self means or family” (79%) and had ESI 3 (92%). Among those discharged ( $n = 1383$ ), 60 (4%) returned to the ED within 30 days, and roughly 1% died.

Our analyzed sample of abdominal pain patients on Medicare and discharged from the ED is also summarized in Table 1; records are compared based on whether the patient was imaged in the ED or not. A total of 1385 encounters made by 1006 individuals comprised the sample for this analysis, with 643 abdominal pain encounters imaged in the ED and 742 not imaged inside the ED. Patients who received an image in the ED were, on average, older ( $p < 0.001$ ) and

had a lower heart rate ( $p < 0.001$ ) than patients who were not imaged in the ED. Race ( $p = 0.04$ ) and mode of arrival ( $p = 0.01$ ) also differed significantly between the two groups.

Individuals who were not imaged in the ED were associated with a significantly higher unadjusted odds of subsequent outpatient imaging within 7, 14, and 28 days after being discharged by a factor of 6.1 (95% CI 3.90–9.54,  $p < 0.001$ ), 4.39 (95% CI 3.04–6.34,  $p < 0.001$ ), and 2.97 (95% CI 2.2–4.0,  $p < 0.001$ ), respectively (Table 2). After baseline demographic and underlying health needs variables were added to the final model, individuals who were not imaged in the ED were associated with a significantly higher adjusted odds of subsequent outpatient imaging within 7, 14, and 28 days after being discharged by factors of 6.65 (95% CI 3.96–11.17,  $p < 0.001$ ), 4.69 (95% CI 3.11–7.07,  $p < 0.001$ ), and 3.1 (95% CI 2.25–4.27,  $p < 0.001$ ), respectively (Table 2). As mentioned, results for the same adjusted model of subsequent advanced imaging after removing Medicare patients that were less than 65 years of age were obtained for sensitivity and are presented in the online supplement (Table S1). The aORs of this sensitivity analysis were larger than the aORs presented above, when all Medicare patients were included.

Individuals who were not imaged in the ED were also associated with a significant increase in the odds of revisiting the study ED within 30 days of being discharged by a factor of 1.81 (95% CI 1.42–2.3,  $p < 0.001$ ). After baseline demographic and underlying health needs variables were added to the final model, individuals who were not imaged in the ED were also associated with a significantly higher adjusted odds of revisiting the study ED within 30 days after being discharged by a factor of 1.65 (95% CI 1.29–2.12,  $p < 0.001$ ; Table 2).

Individuals who were not imaged in the ED were associated with a significant increase in the odds of revisiting any ED within 30 days of being discharged by a factor of 1.66 (95% CI 1.32–2.09,  $p < 0.001$ ). After baseline demographic and underlying health needs variables were added to the final model, individuals who were not imaged in the ED were associated with a significant increase in the adjusted odds of revisiting any ED within 30 days after being discharged by a factor of 1.47 (95% CI 1.16–1.86,  $p = 0.001$ ; Table 2).

As mentioned, results for the same adjusted models of 30-day revisit to the study ED and 30-day revisit to any ED after removing Medicare patients who were less than 65 years of age were obtained for sensitivity and are presented in the online supplement (Table S1). We remark that the aORs were larger than the aORs presented above when compared to all Medicare patients.

Lastly, we investigated the possibility that ED congestion and physician workload may affect the association between no imaging in the ED and subsequent imaging outside the ED. ED imaging rates by congestion and physician workload tertile are summarized in the online supplement (Table S3). We found that the association between no imaging in the ED and subsequent imaging outside the ED remained significant for low, medium, and high ED congestion and physician workload (Table 2). In particular, this association was highest for the 7-day outcome when congestion and physician workload levels were highest, but CIs for all levels of congestion and workload overlapped.

**TABLE 1** Baseline characteristics of abdominal pain patients discharged from the ED

Variable	Overall	Image in ED	No image in ED	p-value
	(N = 1385)	(n = 643)	(n = 742)	
Age (years)	60.4 ( $\pm$ 17.7)	63.4 ( $\pm$ 16.8)	57.8 ( $\pm$ 18.0)	<0.001
Income (\$K)	63.3 ( $\pm$ 16.4)	63.7 ( $\pm$ 16.1)	62.9 ( $\pm$ 16.6)	0.4
Heart rate (beats/min)	83.2 ( $\pm$ 17.1)	82 ( $\pm$ 16.3)	84.1 ( $\pm$ 17.6)	0.02
Blood pressure (mm Hg)	77.2 ( $\pm$ 14.4)	77 ( $\pm$ 13.9)	77.4 ( $\pm$ 14.8)	0.6
Respiration (beats/min)	18.1 ( $\pm$ 2.8)	18.1 ( $\pm$ 2.9)	18.1 ( $\pm$ 2.8)	1
Temperature ( $^{\circ}$ F)	97.6 ( $\pm$ 0.7)	97.6 ( $\pm$ 0.7)	97.6 ( $\pm$ 0.7)	0.05
Female	894 (65)	428 (67)	466 (63)	0.2
Race/ethnicity				0.003
White	1192 (86)	576 (90)	616 (83)	
Black/African American	137 (10)	50 (8)	87 (12)	
Hispanic	<30 (<3)	<10 (<1)	<25 (<4)	
American Indian/Alaska Native	<10 (<1)	<10 (<1)	<10 (<1)	
Asian	<20 (<2)	<10 (<1)	<10 (<1)	
Self means of arrival or family	1093 (79)	523 (81)	570 (77)	0.05
Mortality	<10 (<1)	<10 (<1)	<10 (<1)	0.9
Acuity = 3	1273 (92)	589 (92)	684 (92)	0.8
Diabetes without complications	178 (13)	81 (13)	97 (13)	0.9
Diabetes with complications	121 (9)	55 (9)	66 (9)	0.9
Congenital heart failure	74 (5)	37 (6)	37 (5)	0.6
Hypertension	693 (50)	333 (52)	360 (49)	0.2
Obesity	276 (20)	119 (19)	157 (21)	0.2
<b>Outcomes</b>				
Imaging outside ED within 7 days	166 (12)	24 (4)	142 (19)	<0.001
Imaging outside ED within 14 days	203 (15)	39 (6)	164 (22)	<0.001
Imaging outside ED within 28 days	264 (19)	69 (11)	195 (26)	<0.001
30-day revisits to the study ED	386 (28)	139 (22)	247 (33)	<0.001
30-day revisits to any ED	447 (32)	170 (26)	277 (37)	<0.001

Note: Data are reported as mean ( $\pm$ SD) or *n* (%). Imaged patients were compared to patients who were not imaged using a two-sample t-test for continuous variables and a chi-square test for categorical variables.

## DISCUSSION

We examined associations between lack of advanced imaging in the ED on the risk of subsequent imaging outside the ED and 30-day revisits for Medicare patients presenting to the ED with abdominal pain who were discharged home from the ED. Our main finding is that lack of imaging in the ED was associated with significantly higher odds of imaging outside the ED within 7, 14,

and 28 days of being discharged from the ED. This association remained significant for different levels of congestion and physician workload. No imaging in the ED was also associated with significantly higher odds of revisiting the study ED and any ED within 30 days.

Our results also showed a nonsignificant trend toward higher post-ED utilization of imaging among patients who were not imaged at times of higher ED crowding and physician workload. These

	OR (95%)	p-value	Adjusted OR (95%)	p-value
Imaging outside ED within 7 days	6.1 (3.9–9.54)	<0.001	6.65 (3.96–11.17)	<0.001
Congestion				
Low			4.68 (1.86–11.8)	<0.001
Medium			9.17 (3.98–21.14)	<0.001
High			8.36 (3.7–18.89)	<0.001
Workload				
Low			2.75 (1.19–6.32)	0.02
Medium			9.98 (4.48–22.21)	<0.001
High			12.49 (5.14–30.33)	<0.001
Imaging outside ED within 14 days	4.39 (3.04–6.34)	<0.001	4.69 (3.11–7.07)	<0.001
Congestion				
Low			3.84 (1.77–8.33)	<0.001
Medium			5.08 (2.65–9.75)	<0.001
High			5.78 (2.94–11.35)	<0.001
Workload				
Low			3.15 (1.52–6.5)	0.002
Medium			5.09 (2.68–9.67)	<0.001
High			7.72 (3.67–16.24)	<0.001
Imaging outside ED within 28 days	2.97 (2.2–4)	<0.001	3.1 (2.25–4.27)	<0.001
Congestion				
Low			2.48 (1.38–4.45)	<0.001
Medium			3.3 (1.95–5.58)	<0.001
High			4.04 (2.28–7.15)	<0.001
Workload				
Low			2.37 (1.41–3.97)	0.001
Medium			2.97 (1.76–5.01)	<0.001
High			5.20 (2.82–9.58)	<0.001
30-day revisits to study ED	1.81 (1.42–2.30)	<0.001	1.65 (1.29–2.12)	<0.001
30-day revisits to any ED	1.66 (1.32–2.09)	<0.001	1.47 (1.16–1.86)	0.001

**TABLE 2** Unadjusted and adjusted OR (95% CI) of being imaged outside the ED within 7, 14, and 28 days of discharge and of revisiting ED within 30 days of discharge

Note: Adjusted ORs (95% CI) of being imaged outside the ED within 7, 14, and 28 days of discharge by congestion and physician workload tertile.

results corroborate with other analyses of claims data to estimate post-ED utilization<sup>12</sup> and suggest that when evaluating the effects of operational stress on ED decision making, downstream outcomes must be taken into account.

Taken together, these results suggest that imaging in the ED is associated with lower subsequent imaging utilization outside the ED and with lower 30-day revisit rates in this population. These findings are consistent with prior work evaluating the relationship between ED imaging and revisits;<sup>5,13</sup> however, this analysis uses claims data to also examine other sources of outpatient post-ED care.

## LIMITATIONS

We remark that the analysis is performed at a single center among Medicare beneficiaries only, so results may not be generalizable to the general population. Specifically, our population generally consisted of older adults with access to follow-up care, and further work is needed to evaluate the relationship between imaging and follow-up in a more generalized ED population. Finally, our findings are based on retrospective data, with the likelihood of unmeasured covariates; therefore, results should be interpreted with caution in making recommendations for clinical practice.

While specific guidelines exist to cover certain abdominal imaging scenarios including trauma<sup>14</sup> or suspected appendicitis,<sup>15</sup> abdominal pain as an entity was chosen specifically for study, as across all presentations there is no consensus strategy for imaging. While this analysis presumes that the decision to image abdominal pain influences follow-up imaging, it is possible in some cases the causality is reversed: physicians may avoid imaging in the ED if they are aware that a patient will be receiving imaging as outpatients in close follow-up or may formulate a “wait and see” approach to imaging.

## CONCLUSIONS

In summary, this work extends our understanding of the association between cross-sectional imaging for abdominal pain and downstream medical care utilization, suggesting that imaging in the ED may have a protective effect against future imaging and highlighting the importance of considering overall care trajectories when assessing the impact of care performed in the ED.

## AUTHOR CONTRIBUTIONS

All authors contributed to the conceptualization of the paper. Valerie Odeh Couvertier, Brian W. Patterson, and Gabriel Zayas-Cabán designed and performed the data analysis. Gabriel Zayas-Cabán, Valerie Odeh Couvertier, and Brian W. Patterson drafted the paper. All authors provided critical feedback of the paper and gave final approval of the paper.

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## CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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