Reducing Abdominal Radiographs to Diagnose Constipation in the Pediatric Emergency Department

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Objective To determine the frequency of abdominal radiographs obtained in healthy children aged 6 months to 18 years to diagnose constipation in a pediatric emergency department, and evaluate the impact of quality improvement (QI) interventions on their use.

Study design QI study over 2.5 years at a large urban quaternary care children's hospital emergency department. Interventions consisted of educational presentations and individualized abdominal radiograph data reporting. The primary outcome measure was the percentage of abdominal radiographs performed on healthy patients discharged home with a diagnosis of constipation before and after QI interventions.

Results The baseline total percentage of abdominal radiographs performed in otherwise healthy children discharged home with a diagnosis of constipation was 36% (October 2016 to January 2018). According to questionnaire results, ruling out obstruction was the most common reason for ordering an abdominal radiograph. After the QI interventions, the total percentage of abdominal radiograph decreased to 18% (April 2018 to March 2019). This 18% decrease was significant ($P < .001$) and sustained over a 12-month follow-up period. Throughout the study period, the average length of stay was 1.07 hours longer for children who had an abdominal radiograph. Clinically important return visits to the emergency department were uncommon during the postintervention phase (125/1830 [6.8%]), and not associated with whether or not an abdominal radiograph was performed at the initial visit.

Conclusion After these QI interventions, we noted a significant and sustained decrease in the percentage of abdominal radiographs obtained for otherwise healthy patients discharged home with a diagnosis of constipation. *(J Pediatr 2020;225:109-16)*.

Constipation is one of the most frequent causes of acute abdominal pain, accounting for more than 880 000 emergency department (ED) visits in 2014, which is a 78% increase in frequency from 2006.[1,2] In the pediatric population, the prevalence of constipation ranges widely from 0.7% to 29.6%, depending on the clinical criteria applied to make the diagnosis.[3,4] Constipation is also frequently encountered in the pediatric ED (PED), with reported estimates of 19%-25% of pediatric patients presenting with abdominal pain ultimately diagnosed with constipation.[5,6] The frequency of constipation-related ED visits in pediatrics is also increasing, with infants less than 1 year of age having the highest rate of ED visits in both 2006 and 2011 and the 1- to 17-year-old age group experiencing a 50% increase in ED visits from 2006 to 2011.[7] Diagnosing and treating childhood constipation results in healthcare use that is 3 times higher than that of children without constipation, amounting to US$3.9 billion per year.[8] Contributing to these costs is the increasing use of diagnostic imaging in this common diagnosis.

In 2014, the North American and European Societies of Pediatric Gastroenterology, Hepatology and Nutrition created evidence-based guidelines to assist providers in the workup and management of pediatric constipation.[9] These recommendations apply the Rome III criteria, the most widely accepted definitions for constipation.[10,11] These clinical guidelines argue that the diagnosis of constipation rely on a careful history and physical examination alone. They are based on evidence that has shown abdominal radiographs to be unreliable in establishing an association between clinical symptoms of constipation and fecal load on abdominal radiographs.[9-14] Furthermore, some pediatric studies have shown abdominal radiographs to be associated with increased admission rates, increased PED revisits, and have led to clinically important misdiagnoses.[15-18]

ED	Emergency department
EMR	Electronic medical record
LOS	Length of stay
PED	Pediatric ED
PEM	Pediatric emergency medicine
PDSA	Plan-Do-Study-Act

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Despite existing clinical guidelines, considerable variability continues in the approach to constipation in the PED, including high rates of abdominal radiographs; 30%-90% of children presenting to the PED for constipation underwent an abdominal radiograph during their visit.[6,17-24]

The objectives of this study were 2-fold. First, we wanted to evaluate our institution's baseline rates of abdominal radiograph use in the PED workup of constipation. Then we aimed, through educational interventions and individualized data reports, to decrease the percentage of abdominal radiographs for low acuity, otherwise healthy patients presenting to our PED who were ultimately discharged home with a diagnosis of constipation.

Methods

Our institution is a 495-bed, urban, freestanding quaternary care children's hospital located in Los Angeles, California. Our PED has more than 90 000 visits annually, and is staffed by pediatric emergency medicine (PEM) attendings and fellows, urgent care pediatricians, pediatric nurse practitioners, and resident physicians. Our PED is geographically separated into 2 sections. One area is staffed by PEM attendings and fellows along with resident physicians. The other section is staffed by urgent care pediatricians and pediatric nurse practitioners, who generally see lower acuity patients. The study authors consisted of a PEM attending, 2 pediatric resident physicians, and 1 data analyst/evaluator. The Standards for QUality Improvement Reporting Evidence (SQUIRE 2.0) guidelines were applied in the write-up of this project.[25] The institutional review board approved this study.

Our primary outcome was the percentage of abdominal radiographs performed on healthy patients discharged home with a diagnosis of constipation. We included all healthy patients aged 6 months to 18 years old who were discharged home from the PED with a diagnosis of constipation between October 2016 and March 2019 and extracted their demographic, medical, and PED visit information from the electronic medical record (EMR). Because our target patient population was healthy children presenting to our PED, we excluded patients with any significant past medical history that would either complicate the patient's assessment or expand their differential diagnoses. For the purposes of this study, the study authors created a list of significant past medical history to be used as exclusion criteria, which included diseases such as cerebral palsy, developmental delay, autism spectrum disorder, congenital heart disease, chronic lung disease, renal disease, epilepsy, cancer, history of ventriculoperitoneal shunt, history of any abdominal surgery, and chronic gastrointestinal disease (of note, we included chronic constipation). Study authors identified past medical history through data abstraction from each patient's EMR. Similarly, we excluded any encounter in which the presentation suggested the possibility of a more severe illness or the strong potential for an alternative diagnosis. Therefore, any encounter that involved imaging other than an abdominal radiograph or subspecialty consultations, as evidenced by orders placed in the EMR, were also excluded from our study. We held exclusion criteria consistent throughout the study period.

Interventions and Postintervention Phase

We developed Plan-Do-Study-Act (PDSA) cycles to target behavior change in our PED providers through education and personalized data reporting (**Figure 1**; available at www.jpeds.com). This project's timeline spanned 16 months of baseline (preintervention) data (from October 2016 through January 2018), 2 months implementing the interventions (February and March 2018), and 12 months of postintervention data (from April 2018 to March 2019).

Additionally, before the first PDSA cycle, 2 of the study authors informally surveyed 20 PED providers, asking the following open-ended question: "What are reasons why you would order an abdominal radiograph in an otherwise healthy patient who you suspect has constipation based on history and physical exam?" As a part of the plan phase, the authors used these responses to tailor their educational material. The first intervention, the educational presentation, aimed to educate PED providers and familiarize them with the QI project. The study authors provided two 20-minute long presentations to the PED providers during a bimonthly staff meeting at the end of February 2018 (1 presentation to our PEM attending physicians and fellows and 1 for the urgent care pediatricians and nurse practitioners who staff the urgent care area of the PED). This oral presentation with supplemental PowerPoint, reviewed diagnostic criteria for constipation per Rome III criteria, clarified indications for abdominal radiograph, and introduced baseline data and the QI project aim. At the initiation of the project, we consulted with pediatric subspecialists from the hospital's divisions of gastroenterology and radiology for their expertise. They assisted with reviewing and confirming the accuracy of the content of the educational presentation and attended these presentations to field questions and reinforce the multidisciplinary support for this QI initiative. We then sent an email summarizing the presentation for all the PED providers to reference, and for the providers, including all pediatric resident housestaff, who were not in attendance to independently review the same educational material.

In mid-March 2018, we sent a personalized data report via email to each PED provider (PEM attending physicians, PEM fellows, urgent care pediatricians and pediatric nurse practitioners, for a total of 43 providers). This email included the provider's baseline abdominal radiograph frequency in comparison with division-wide frequency and a brief summary of the QI project, including a reminder of the Rome III criteria for the diagnosis of constipation. We presented individualized data in bar graph format, depicting abdominal radiograph frequency, for the inclusion population only, as a proportion of total constipation encounters month to month, from October 2016 to September 2017 (**Figure 2**; available at www.jpeds.com).

Seven months later, in October 2018, we conducted an interim analysis and sent out a second email, similar to the first, with an individualized data report to each PED provider with his or her baseline and interim abdominal radiograph frequency from April 2018 to June 2018, in comparison with the entire division. This email again reinforced the project aim and summarized key educational points (**Figure 3**; available at www.jpeds.com). During the same month, we distributed a brief anonymous questionnaire (including both free response and multiple choice questions) to once again assess PED providers' reasons for ordering abdominal radiographs in patients suspected to have constipation, and their recall and perceptions of the educational content and personalized metrics (**Figure 4**; available at www.jpeds.com). In this questionnaire, we explicitly asked providers whether they thought our interventions affected their practice and which intervention (educational presentation vs personalized data) had a greater influence.

We collected data through March 2019, 1 year from the start of the QI interventions, and 5 months following the last intervention.

Data Preparation

Clinical data were extracted from our hospital's EMR system. All patient encounters were reviewed by 2 of the authors for exclusion criteria and their codes were compared for agreement beyond chance (using the Cohen Kappa as a measure of interrater reliability). Discrepant codes were resolved by the senior author.

Statistical Analyses

Data were analyzed using summary statistics (mean, SD, 95% CI of the mean, frequencies, percentages). The 2-sample *z*-test for difference between proportions was used to compare overall abdominal radiograph percentages from the preintervention and postintervention phases. The statistical process control chart that we specifically used to examine abdominal radiograph percentages over time was the P-chart with the upper and lower control limits set to 3 sigma.[26] As a balancing measure, we also looked at all the ED return visits within 7 days of the initial encounter.

Results

During the 30-month study period, there were a total of 5696 encounters by 5084 patients meeting our inclusion criteria, with an average of 190 ± 31 encounters per month, in which an otherwise healthy child was diagnosed with constipation and discharged home. Before, during, and after the QI interventions, the Cohen Kappa for encounter exclusions was at least 0.80, which indicated an acceptable level of agreement beyond chance. Of the total 5084 patients seen, 2820 patients (55.5%) were female. The mean patient age was 7.1 years ± 4.5.

In the preintervention period, the baseline departmental percentage of abdominal radiographs was 36% with SD 3.9% (1190 of 3314 PED encounters during October 2016 to January 2018). The percentage of abdominal radiographs during the intervention period was 26% (109 of 413 encounters for February and March 2018). Specifically, the percentage of abdominal radiographs in February 2018 was 35%, and in March 2018 was 17.5%. After the QI interventions, the total percentage of abdominal radiograph decreased to 18% ± 3.9% (359 of 1969 PED encounters during the 12-month postintervention period from April 2018 to March 2019) (**Figure 5**). This 18% decrease was significant ($P < .001$).

As described, our PED is separated into 2 geographic sections staffed by different provider types. When stratified by provider type, the preintervention baseline abdominal radiograph rate for PEM attendings and fellows was 43% (610 of 1433 encounters) and postintervention decreased to 21% (148 of 694 encounters) (**Figure 6**). For the urgent care pediatricians and pediatric nurse practitioners, the preintervention baseline abdominal radiograph was 31% (580 of 1881 encounters) and postintervention decreased to 16.5% (210 of 1275 encounters). Although the pediatrician/nurse practitioner group had lower preintervention and postintervention abdominal radiograph frequencies compared with the PEM providers, we noted a greater decrease in abdominal radiograph frequency from preintervention to postintervention among the PEM providers, 22%, compared with the 14.5% decrease for the pediatrician/nurse practitioner group.

Thirty-nine providers completed the interim questionnaire, which was distributed 7 months after the initial interventions and midway through the follow-up phase. When asked why they would order an abdominal radiograph in an otherwise healthy child with history and physical supporting a diagnosis of constipation, the most common reasons were to rule out obstruction (29.1%), associated vomiting (20%), and parental reassurance (16.4%). When asked to recall which intervention had the greatest impact on their abdominal radiograph ordering practice, 41% reported that the individualized data reports were most impactful, and 33% found the educational presentation most impactful (**Table I**; available at www.jpeds.com). Ten percent of the providers felt neither the presentation nor the report had any impact on their practice.

For all encounters throughout the study, a child who had an abdominal radiograph spent on average 1.07 more hours in the PED than a child who did not receive an abdominal radiograph. Furthermore, the average length of stay (LOS) did not change significantly after implementation of the interventions, as indicated by the overlapping confidence intervals for encounters with and without abdominal radiograph. Specifically, for the preintervention data, the mean LOS for encounters with abdominal radiograph was 3.43 hours (95% CI, 3.34-3.52) and without abdominal radiograph was 2.4 hours (95% CI, 2.34-2.46). For the postintervention data, the mean LOS for encounters with abdominal radiograph was 3.5 hours (95% CI, 3.32-3.68)

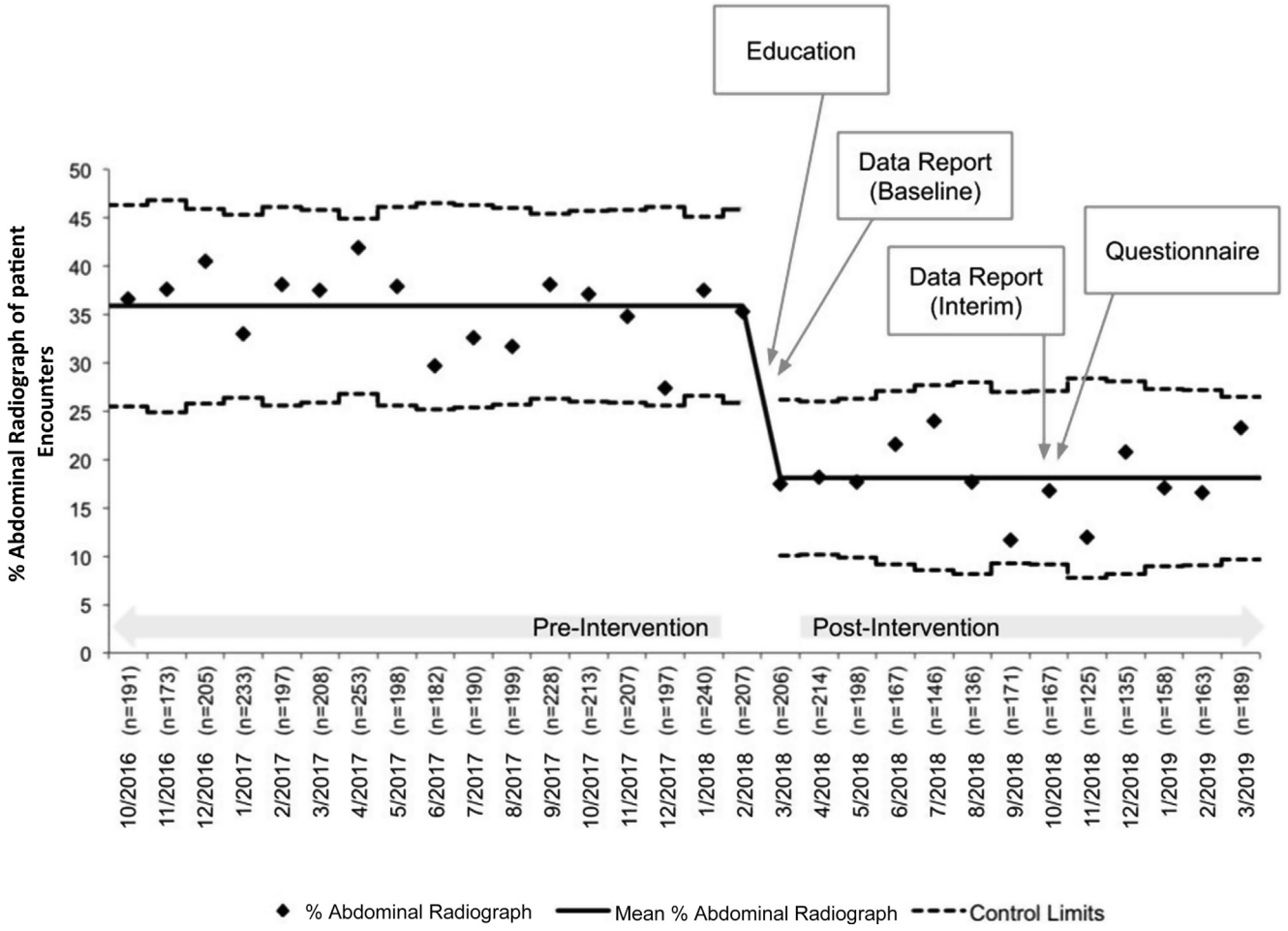

Figure 5. Annotated p-chart showing abdominal radiograph frequency by month throughout the preintervention (October 2016 to January 2018), intervention (February to March 2018), and postintervention periods (April 2018 to March 2019).

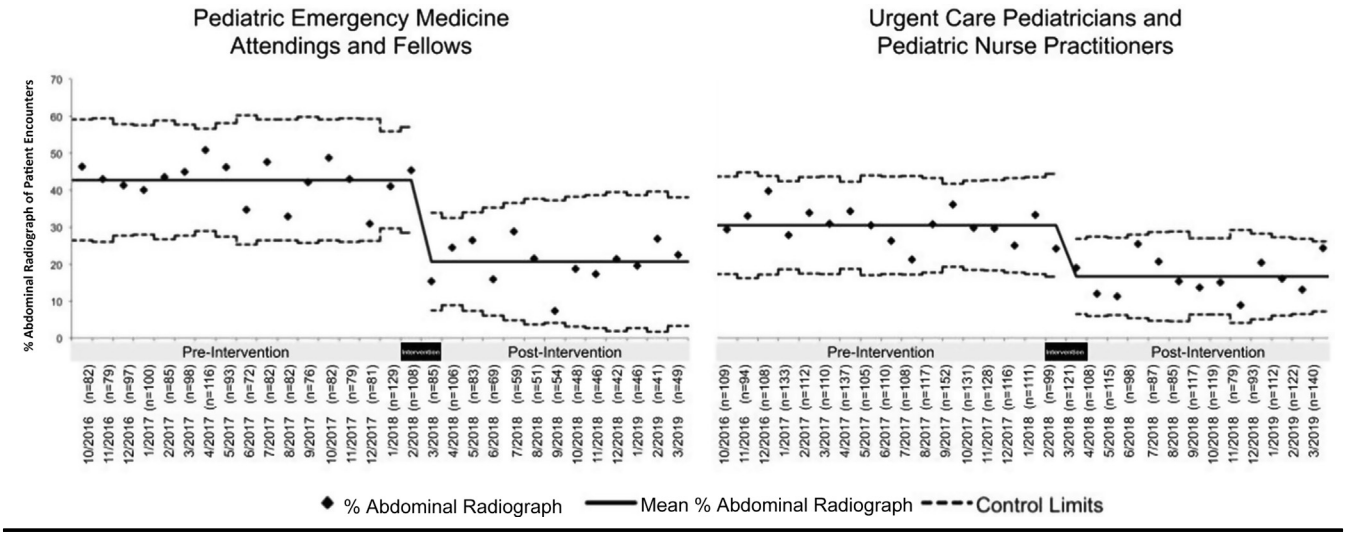

Figure 6. Side-by-side p-charts showing abdominal radiograph frequency by month stratified by provider type, PEM providers (attendings and fellows) as compared with urgent care providers (pediatricians and nurse practitioners).

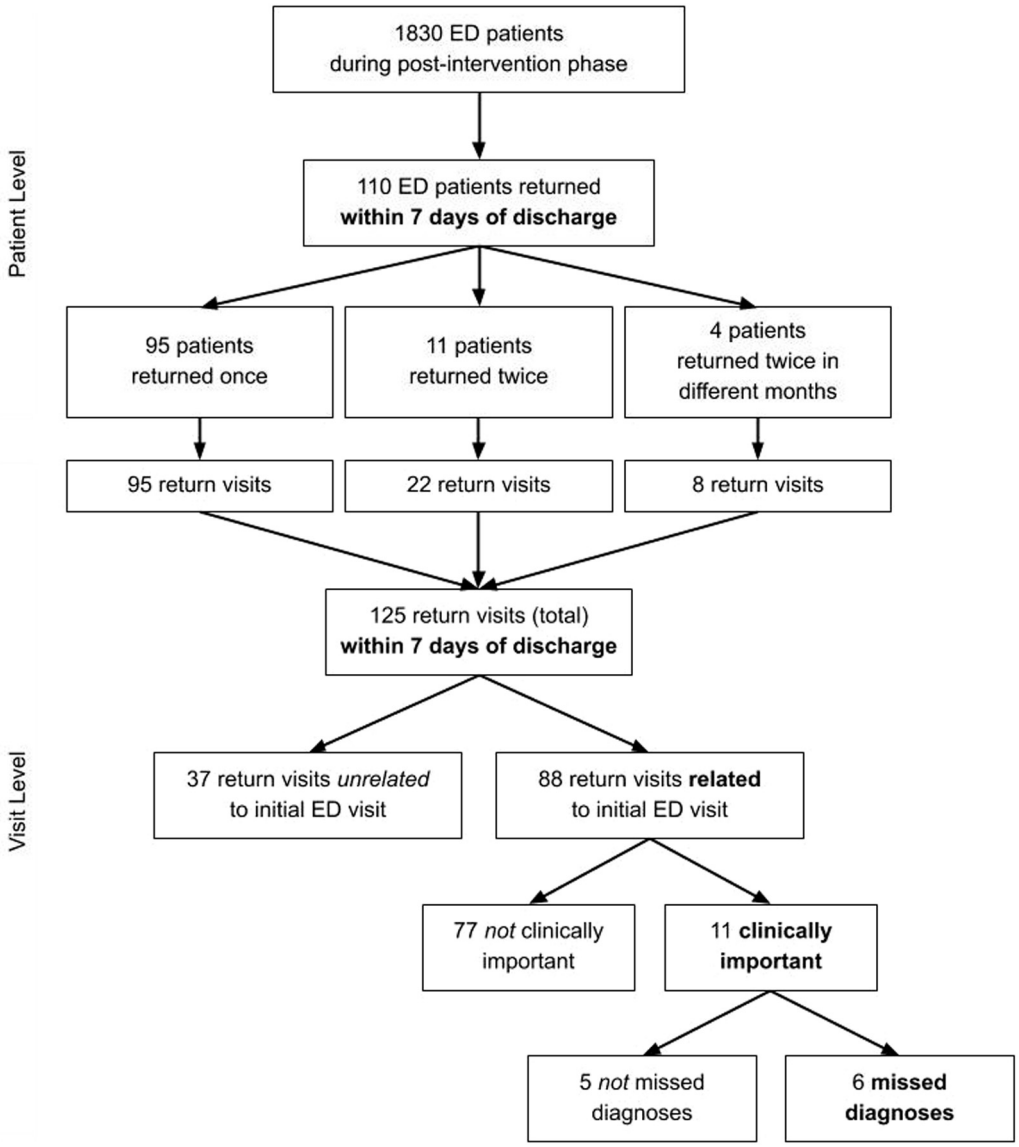

Figure 7. Flow chart of patients who returned within 7 days of discharge from PED with a diagnosis of constipation.

and without abdominal radiograph was 2.39 hours (95% CI, 2.32-2.46).

As an important balancing measure, we looked at PED return visits within 7 days among all included patients. Of the 1830 PED patients who were seen and discharged home with a diagnosis of constipation during the postintervention phase, there were a total of 125 return visits within 7 days of discharge (6.8%). Of those 125 return visits, 18 (14.4%) had an abdominal radiograph. Eleven (8.8%) of the 125 return visits were clinically important, of which 6 were missed diagnoses. Of the missed diagnoses, 3 (50%) had an abdominal radiograph performed at their initial PED visit, 2 were admitted for appendicitis requiring surgical intervention, 2 were admitted for intravenous hydration, and 2 were admitted for further workup of abdominal pain (**Figure 7** and **Table II**).

Discussion

Our division's baseline percentage of performing abdominal radiograph for healthy children discharged home with a diagnosis of constipation was low, at only 36%, than most other previously published studies, where the baseline abdominal radiograph rate ranged between 27% and 90%.[6,17-24] Despite our institution's lower baseline rate, our QI interventions still resulted in a significant decrease in abdominal radiograph use in the diagnosis of constipation, from 36% to 18% for a 50% reduction, which was sustained throughout the 12-month follow-up period.

Our study shows that even within a division that has a relatively low baseline abdominal radiograph frequency in the workup of this common diagnosis, QI interventions can still lead to a significant improvement in quality of care, and

Table II. Demographic characteristics and visit details of patients with clinically significant return visits within 7 days of initial ED visit

Ages (years)	Sex	Presenting complaint at initial visit	Abdominal radiograph obtained at initial visit	Time between initial and return visit	Final diagnosis, return visit	Missed diagnosis	Disposition
14	M	Vomiting	Yes	11 h	Appendicitis	Yes	Admitted for surgery
6	F	Abdominal pain	No	3 days	Dehydration, acute vomiting, hypoglycemia, hyperkalemia	Yes	Admitted for dehydration*
9	M	Abdominal pain	No	3 days	Nephrolithiasis	Yes	Admitted for pain control and further workup†
5	M	Abdominal pain	Yes	7 days	Acute gastroenteritis, ileus	Yes	Admitted for bowel rest and intravenous fluids
9	M	Abdominal pain	No	3 days	Appendicitis	Yes	Admitted for surgery
10	F	Abdominal pain	Yes	3 days	Small intestinal bacterial overgrowth	Yes	Admitted for further workup of abdominal pain
14	F	Abdominal pain	Yes	2 days	Abdominal pain	No	Admitted for stool cleanout
8	M	Diarrhea	Yes	2 days	Fecal impaction, encopresis, Shigella infection	No	Admitted for stool cleanout
6	F	Abdominal pain	Yes	1 day	Abdominal pain, constipation, diarrhea	No	Admitted for stool cleanout
6	F	Genitourinary complaint	No	7 days	Fever, abdominal pain, constipation, acute UTI, vulvovaginitis	No	Discharged home from ED‡
1	F	Fever	No	2 days	Constipation	No	Admitted for stool cleanout

UTI, urinary tract infection.
*Two ED return visits within 7 days of the initial visit. Abdominal radiograph and urinalysis completed at return visit. Discharged home after tolerating oral rehydration in the ED with diagnosis of vomiting and diarrhea. Represented to ED the following day, intussusception ultrasound negative, chemistry consistent with dehydration and hypoglycemia.
†Patient initially admitted with a diagnosis of appendicitis based on preliminary ultrasound results. Computed tomography scan of the abdomen/pelvis revealed normal appendix with evidence of right upper urinary tract inflammation from passed kidney stone vs infection.
‡Although the patient was discharged home from the ED, she returned the following day with continued fevers and was ultimately admitted for *E coli* bacteremia and pyelonephritis.

without the unintended consequences of missed and delayed diagnoses. Clinically important return visits and missed diagnoses were overall infrequent in our study period, and lacked any association to whether an abdominal radiograph was performed at the first visit, mirroring what we see in the literature. Furthermore, when we analyzed the overall population of patients 6 months to 18 years of age, regardless of exclusion criteria, who were diagnosed and discharged with constipation during the study period, we noted higher abdominal radiograph rates preintervention and postintervention as compared with our specific inclusion population. However, we also discovered a nearly 50% decrease in the abdominal radiograph rate among this overall population. Specifically, during the preintervention period, total abdominal radiograph rate for all patients 6 months to 18 years of age was 39.5% (1550/3926), and during the postintervention period, total abdominal radiograph rate for those 6 months to 18 years of age decreased to 20.7% (478/2311).

Our study also exposed practice and diagnostic approach variations among the different types of providers in our PED. There are several possible explanations for these provider-level differences. One is that, generally, patients seen by PEM providers tend to have a more acute and complex clinical presentation, perhaps leading providers to include more testing such as abdominal radiographs. We attempted to mitigate this through our exclusion criteria, although subtle differences between patients seen in the urgent care vs the main PED likely persisted. Additionally, PEM providers routinely care for the sickest patients in the PED and may inadvertently allow the cognitive bias, availability heuristic, to overestimate the likelihood of something aside from constipation.

Our findings complement studies that apply educational interventions to improve the quality of care in the diagnosis of constipation in the PED. Through the use of educational presentations with ED providers or the creation of a standardized ED constipation management pathway, previous studies have shown success in reducing abdominal radiograph use anywhere from 40% to 48%.[22-24] Our study adds to the literature by successfully using individualized metric reporting at multiple time points throughout the study period as a means of motivating and streamlining behavior change across the division. Through the application of 1-on-1 provider interviews and questionnaires, our study also integrates practitioner level feedback during the design and intervention phases to better understand the actual impact of our interventions on clinical decision-making.

Wasteful spending and overuse of resources is a well-known problem in US healthcare, with estimates of roughly 50% of healthcare spending classified as waste.[27] The PED visits during our study period without abdominal radiograph were, on average, 1 hour shorter than those with an abdominal radiograph. LOS is an important contributor to the overall cost of a patient encounter, both for the healthcare system and the individual patient, and is routinely part of cost analyses.

There is a growing movement to decrease the overuse of testing in all fields of medicine, including pediatrics, through efforts such as the Choosing Wisely Campaign, which is endorsed by 9 American subspecialty organizations.[28-33] There is also an enhanced understanding that unnecessary care has inherent risks and costs, either providing no benefit to patient outcomes or even promoting harm.[34,35] In a comparative study between the US and Canada, abdominal radiograph and computed tomography scan rates for abdominal pain and constipation in children were significantly lower in Canada compared with the US, without any meaningful difference in outcomes, suggesting that imaging rates can safely be decreased in the US.[36]

The medical community's recognition of the potential harm of unnecessary radiation exposure to children has gained attention and action.[37,38] In addition to the inherent risks of radiation, unnecessary imaging adds to the cost of medical care and can lead to the discovery of incidentalomas.[38] This increasing awareness of unnecessary imaging has led to the creation of evidence-based guidelines and nationally accepted algorithms to avoid radiographic imaging in the workup and management of many pediatric diagnoses commonly seen in the PED.[39-41]

One factor that might have played a role in this change in clinical practice over time is the Hawthorne effect.[42] Having a PEM attending as the principal investigator of the QI study and a higher number of PEM providers in attendance at our educational intervention are additional factors thought to play a role in the greater decrease in abdominal radiograph frequency among PEM providers. We attempted to mitigate the potential influence of the Hawthorne effect by extending our postintervention observation period for 12 months to monitor for sustained change once close monitoring had ended. More likely, the results we saw with our QI intervention represented the growing commitment within our division, and throughout medicine more broadly, to reduce unnecessary testing and follow evidence-based practice.

There are several limitations to our study. First, because our cohort pertained to healthy children, our results cannot be extrapolated to describe patients with chronic medical problems or those presenting with more severe or complicated illness. Second, because both interventions occurred in the same 2 months, it is difficult to distinguish which intervention was more impactful on the subsequent changes we observed in providers' behavior. Our questionnaire data showed a mixed proportion of providers who found 1 intervention more impactful than the other, suggesting that a multifaceted approach should be implemented to account for variability in preferences and influences. Third, our analysis did not track whether a decrease in abdominal radiographs resulted in a concomitant increase in other imaging studies such as computed tomography scans or ultrasound examinations.

QI educational interventions and personalized data resulted in a direct and sustained change in practice patterns across multiple provider groups at a single institution's PED. Our study contributes to the growing movement to decrease unnecessary testing while providing guideline-based, safe, and efficient patient care. ■

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Data Statement

Data sharing statement available at www.jpeds.com.

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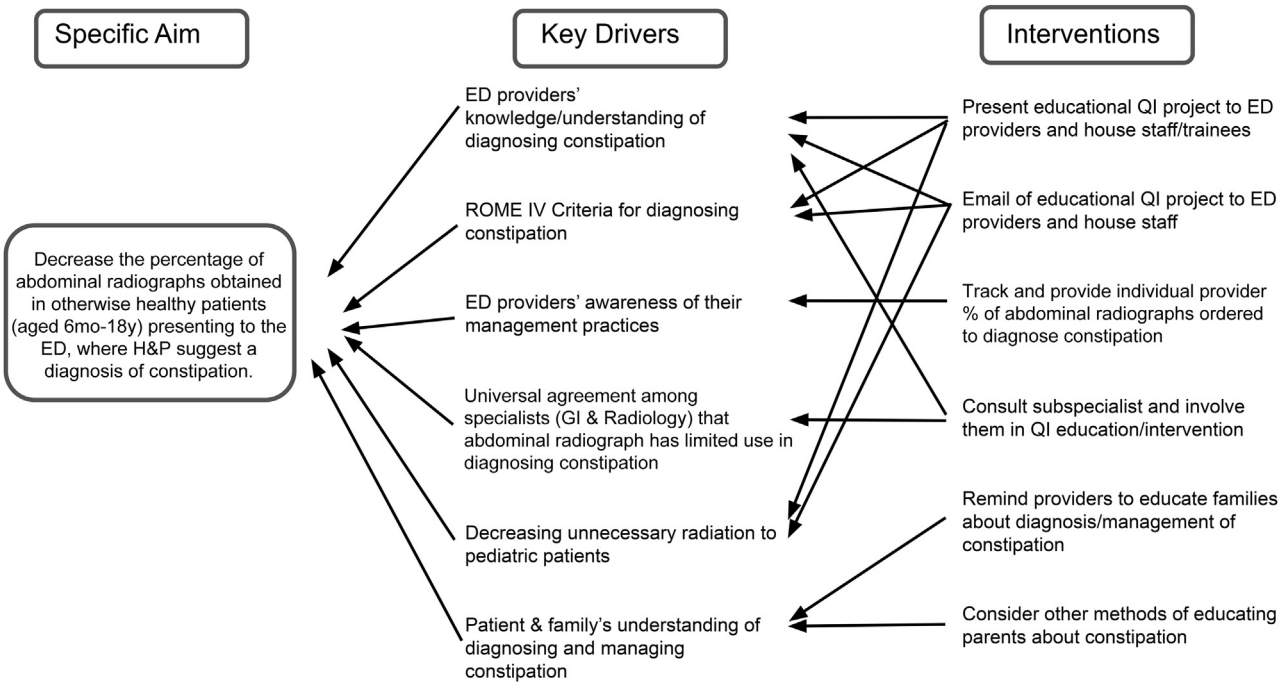

Figure 1. Key driver diagram. *H&P*, history and physical examination.

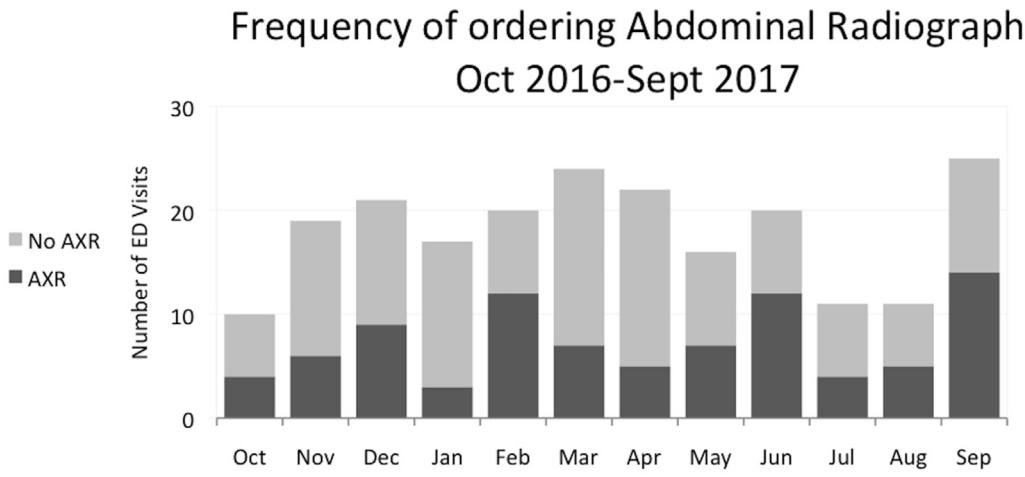

Figure 2. Example of initial email to each provider with individualized baseline data.

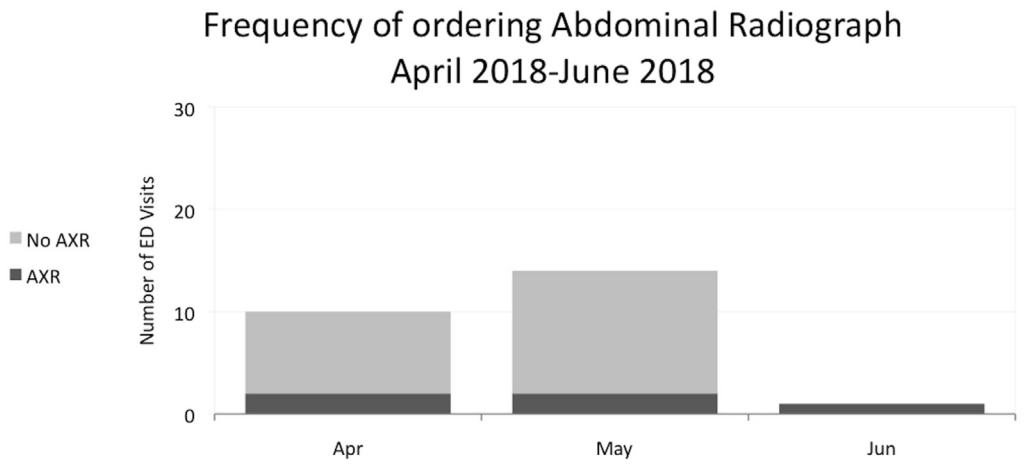

Figure 3. Example of interim email to each provider with individualized interim data.

1. In an otherwise healthy child (without chronic medical problems, developmental delay, or previous GI diagnoses) with history and physical pointing towards a diagnosis of constipation, what are reasons why you would order an abdominal radiograph?

2. Did you attend the presentation about a Constipation QI project held at the departmental meeting in February 2018 about decreasing the number of abdominal radiographs ordered in the workup of constipation?
    a. Yes
    b. No
    c. I did not attend but I read the follow-up email
    d. I can't remember

3. If you answered with A or C above, did that presentation or email have any impact on how you approach healthy children as described above suspected to have constipation? Why or why not?
    a. Yes
    b. No

4. Do you remember receiving an email about the Constipation QI project with your individualized baseline data of number of abdominal radiographs ordered in children discharged home with diagnosis of constipation?
    a. Yes
    b. No

    If you said yes to the question above, were you surprised about your results? Why or why not?
    a. Yes
    b. No

5. Did that email have any impact on how you approach healthy children as described above suspected to have constipation? Why or why not?
    a. Yes
    b. No

6. In the last year, do you think you order more or less abdominal radiographs compared to the departmental baseline of 36% for healthy patients as described above with history and physical pointing towards a diagnosis of constipation?
    a. More
    b. Less

Figure 4. Anonymous interim questionnaire to providers in October 2018.

Table I. Interim questionnaire results, October 2018

Questions	Frequency (%)
Which intervention was most impactful?	
Individualized data report	16 (41)
Educational presentation	13 (33)
Neither presentation nor report had impact	4 (10)
Didn't attend presentation and can't remember report	5 (13)
Unknown (missing data)	1 (3)
Reasons for impact or no impact of educational presentation	
Impactful for affecting my current practice and/or knowledge	9 (23)
Impactful for confirming my current practice and/or knowledge	7 (18)
No impact because already judicious with abdominal radiographs	6 (15)
Unknown (missing data)	17 (44)
Reactions to individualized data report	
Neutral/confirmed expectations	12 (31)
Appreciated seeing personalized metrics	3 (8)
Surprised/personalized metrics lower than expected	2 (5)
Surprised/personalized metrics higher than expected	8 (21)
Can't remember report	14 (36)

Thirty-nine ED providers were surveyed in October 2018.