

# Effectiveness of a radiation reduction campaign targeting children with gastrointestinal symptoms in a pediatric emergency department

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## Abstract

Children feature more active cellular division and a smaller body area, which leads to a greater radiation dosage accumulation. We tried to reduce radiation hazards by reducing unnecessary radiological studies in a pediatric emergency department (PED) through the radiation reduction campaign.

Our campaign involved a reduction from 2 (erect and supine) to 1 ordered abdominal plain radiograph (erect). This quasi-experimental, uncontrolled before-and-after study aimed to evaluate the campaign effect. We compared simple radiograph orders, length of stay (LOS) in PED, and return visit (RV) to PED between the before period (June 1, 2011–May 30, 2014) and the after period (June 1, 2014–May 30, 2015). Piecewise regression was used to assess rate differences between the periods.

A total of 10,729 and 3515 patients were included before and after the campaign, respectively. During study periods, 9647 (90%) and 2710 (77%) total abdominal radiographs were ordered, respectively (rate difference = 13%;  $P < 0.001$ ), and the slopes of rate changes were 0.03 and  $-0.71$ , respectively ( $P = 0.056$ ). The total abdominal erect and supine film rate slope decreased from  $-0.19$  to  $-2.86$  ( $P = 0.004$ ). The RV rate did not change (220 [2%] vs 56 [2%], respectively;  $P = 0.104$ ). The slope of total RV rate changed from  $-0.01$  to  $-0.05$  ( $P = 0.132$ ), and the slope of LOS changed from 0.001 to  $-0.352$  ( $P = 0.243$ ).

The campaign to reduce abdominal radiograph orders in pediatric patients successfully reduced the abdominal plain film X-ray rate without on the RV rate and the LOS.

**Abbreviations:** AE = abdominal erect plain film, AES = abdominal erect-supine plain film, APF = abdominal plain film, AS = abdominal supine plain film, CDW = clinical data warehouse, LOS = length of stay, PED = pediatric emergency department, RV = return visit.

**Keywords:** abdominal plain film, campaign, emergency department, pediatric, radiation

## 1. Introduction

In general, plain X-ray evaluations of patients with gastrointestinal symptoms involve 2 views: supine and erect posture. These examinations are frequently used to screen children with gastrointestinal presentations, especially in pediatric emergency departments (PEDs).<sup>[1–4]</sup> However, abdominal plain X-ray might have limited use as a screening procedure, and the exact indications for erect, supine, and both views have not yet been determined.

Children are 2- to 3-fold more sensitive than adults to ionizing radiation, although this depends on the type of effect (stochastic and deterministic) and age at exposure; however, substantial attention has not been given to the reduction of radiation exposure in PEDs.<sup>[5]</sup> Recently, there have been many efforts to reduce radiation exposure in pediatric populations, and several ongoing studies are attempting to decrease radiation dosage to the extent possible; however, these studies have been limited to computed tomography and did not include plain X-ray.<sup>[1–3,6–12]</sup>

As part of a plan to decrease radiation exposure in children at our institution, we implemented a campaign to reduce the use of abdominal X-rays in children with gastrointestinal symptoms. The objective of this study was to assess the effectiveness of our campaign with respect to the rate of abdominal plain film (APF) usage and the probable effects on patient management and safety parameters, such as the length of stay (LOS), hospital admission, referral to experts for operation, and return visits (RVs).

## 2. Materials and methods

### 2.1. Study design

A quasi-experimental, uncontrolled before-and-after study design was used to evaluate the effects of this campaign in pediatric patients who presented at the emergency department with gastrointestinal symptoms. This study was approved by the hospital institutional review board, and the requirement for informed consent was waived (IRB number: B1511/324-102). This study was performed at an urban tertiary care hospital with

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1100 beds. The hospital receives approximately 80,000 emergency department visits annually; of these, approximately 24,000 involve pediatric patients age 15 years or younger.

## 2.2. Study populations and settings

The campaign was initiated on June 1, 2014. We set the period from June 1, 2011 to May 31, 2014 as the before campaign period, and the period from June 1, 2014 to May 31, 2015 as the after campaign period. All children age 15 years or younger who presented to the PED with the chief complaint of new-onset gastrointestinal symptoms such as abdominal pain, nausea, vomiting, diarrhea, and constipation were included. We excluded patients with pre-existing chronic medical conditions or a history of abdominal surgery, and those who required hospitalization for a poor clinical condition (e.g., sepsis, shock). We used electronic medical records to identify eligible patients and reviewed the records to determine inclusion or exclusion.

## 2.3. Development of a radiation reduction campaign for children with gastrointestinal symptoms in the PED

The committee of pediatric emergency physicians at our institution developed a radiation reduction campaign to target children with gastrointestinal symptoms in the PED, based on published literature regarding APF X-ray. All members of this committee were board-certificated emergency physicians. We held several face-to-face committee meetings and designed the campaign after a structured document search and literature review. This campaign comprised indications, diagnostic performances, and radiation doses of APF X-rays (Table 1).<sup>[1,3,8,9,13–16]</sup> The campaign was performed under the assumption that detailed history taking, physical examination, and information about the radiation doses and effectiveness of APF X-ray might reduce the usage of APF X-ray in the PED. We pledged that this campaign would not be compulsory in order to avoid compromising the decision-making practices of physicians.

## 2.4. Campaign performance and monthly feedback for physicians

We informed emergency physicians about the campaign through monthly educational sessions that were initiated on June 1, 2014. During the campaign period, the committee of pediatric emergency physicians analyzed the charts of all patients subjected to APF X-ray. The total numbers and trends of APF and adverse

events, such as RVs or hospital admissions, were reported monthly to all emergency physicians at our institution.

## 2.5. Methods of measurement

Patients' medical records from June 1, 2011 to May 31, 2015 were collected retrospectively by searching the clinical data warehouse (CDW). Our institution achieved stage 7 on the Electronic Medical Record Adoption Model scale, developed by the Healthcare Information and Management Systems Society Analytics, in 2010. At a stage 7 achievement level, care coordination throughout the hospital is improved by data warehousing, which enables the capture and analysis of care data for performance improvement and clinical decision advancement. The CDW enables access to all medical records within a center. We searched patients' medical charts using a standardized data collection query that included demographics, presenting signs and symptoms, physical examination findings, utilized radiographic studies and their findings, timing of RVs, and adverse events, including mortality, morbidity, intensive care unit admission rate, and abdominal operation rate.

## 2.6. Data analysis

Data were analyzed using Stata statistical software, version 13.1 (Stata Corp LP, College Station, TX). Student *t* test was used for comparisons of continuous variables involving independent samples with normal distributions. A nonparametric analysis was performed for continuous data that did not follow a normal distribution. The 95% confidence intervals were also calculated. Fisher exact test was used for categorical data distributions. All *P* values were 2-tailed, and a *P* value <0.05 was considered statistically significant for all tests.

Piecewise regression was performed to evaluate dynamic changes in the simple radiograph order rate and RV rate following implementation of this campaign in the PED.<sup>[17]</sup> A regression model was used to determine the following parameters:

- (1) slope rate of the before campaign;
- (2) immediate change in the rate following the campaign;
- (3) slope rate of the after campaign;
- (4) difference in slopes between the before and after campaign rates; and
- (5) net effect of the campaign, estimated as the difference between the fitted and expected rates at the beginning of the campaign if the slope was uninterrupted by the campaign.

**Table 1**

### Campaign for radiation reduction in children with gastrointestinal symptoms in the pediatric emergency department.

Catch phrases	Details
Really need abdominal plain film?	Plain radiography in patients with acute abdominal pain has limited additional value. The clinical diagnosis after evaluation of plain radiographs did not change significantly from the primary diagnosis based on clinical evaluation alone
Erect and supine, or erect alone?	Two views of abdominal X-rays (erect and supine) are only useful for certain defined pathology such as abnormal gases, masses, bones, and stones. Except this specific cases, if need, one view (erect) of plain abdominal radiograph is sufficient for screening test
Do you know radiation dose?	Abdominal plain film: 0.7 mSv Chest plain film: 0.02 mSv Abdomen CT <sup>[24]</sup> : 10 mSv Low-dose abdominal CT: 4 mSv One abdominal plain film (erect or supine) has radiation dose of 0.7 mSv and this is 35 times more radiation dose than a chest plain film examination (0.02 mSv). Strategy of one view abdominal X-ray (erect) reduces the radiation dose as same as 35 sheet of chest plain film

CT=computed tomography.

### 3. Results

#### 3.1. Patient characteristics

A total of 10,729 patients were included during the 36-month before campaign period, and 3515 patients were included during the 12-month after campaign period. There were no differences in the distributions of sex or presence of gastrointestinal symptoms except a difference in terms of age between the 2 periods (Table 2).

#### 3.2. Differences in the rate of APF X-ray before and after the campaign

The rates of total APF X-ray and the rates of the 2 views (abdominal erect-supine plain film; AES) decreased significantly after the campaign. The number and rate of single-view X-ray (abdominal erect plain film; AE) increased significantly after the campaign period (Table 2). Piecewise regression was performed to compare the slopes before and after the campaign (Fig. 1; Table 3). The slope of total APF X-ray exhibited a positive trend before the campaign but was negative after the campaign (Fig. 1A). Changes in the slopes of AES and AE were significant after the campaign (Fig. 1B, C). The change in the slope of no APF X-ray was not significant, but the trend shifted from negative to positive (Fig. 1D). The predicted rates of APF, AES, AE, and no APF were considered on or around June 1, 2014 under the assumption that the campaign had not been implemented and any changes would be significant (Table 3).

#### 3.3. Differences in the rate of RVs and LOS before and after the campaign

RVs to the PED and the LOS in the PED were compared as representative indicators of patient care. There were no

significant differences in the RV rate and LOS among the total group of enrolled patients and the RV rates of patients before and after the campaign (Table 4). The RV slope did not significantly change ( $P=0.13$ ; Fig. 1E; Table 5). Similarly, the slope of the LOS in the PED did not significantly change ( $P=0.24$ ; Fig. 1F; Table 5). The difference between the predicted LOS duration and actual measured LOS duration on or around June 1, 2014 was not significant.

### 4. Discussion

To the best of our knowledge, this is the first study to demonstrate the effectiveness of a campaign intended to reduce the exposure of children to radiation from APF X-ray in a PED. We achieved a significant reduction in the total APF X-ray rate and noted a downward shift in the slope of the total APF X-ray rate relative to the rate before the campaign, along with a reduction in the RV rate. The changes in the slopes of the total APF X-ray rate and LOS were not statistically significant, although the shifts in both to a negative trend after the campaign might be notable.

APF X-ray involves 2 traditional views taken in supine and erect positions. These views (supine-erect; both) are frequently included in the screening of children presenting with nonspecific abdominal symptoms.<sup>[18]</sup> In a review regarding the use of APF X-ray in 431 children presenting with abdominal pain at an emergency department, 82% of the examinations revealed findings that were normal, incidental, or misleading with respect to the child's final diagnosis.<sup>[11]</sup> On the other hand, in any of the conditions listed among several high-yield criteria, APF X-ray has a sensitivity >90% with respect to findings diagnostic or suggestive of major abdominal disease. These conditions include prior abdominal surgery, foreign body ingestion, abnormal bowel sounds, abdominal distention, or peritoneal signs.<sup>[2]</sup>

**Table 2**

#### Patient characteristics.

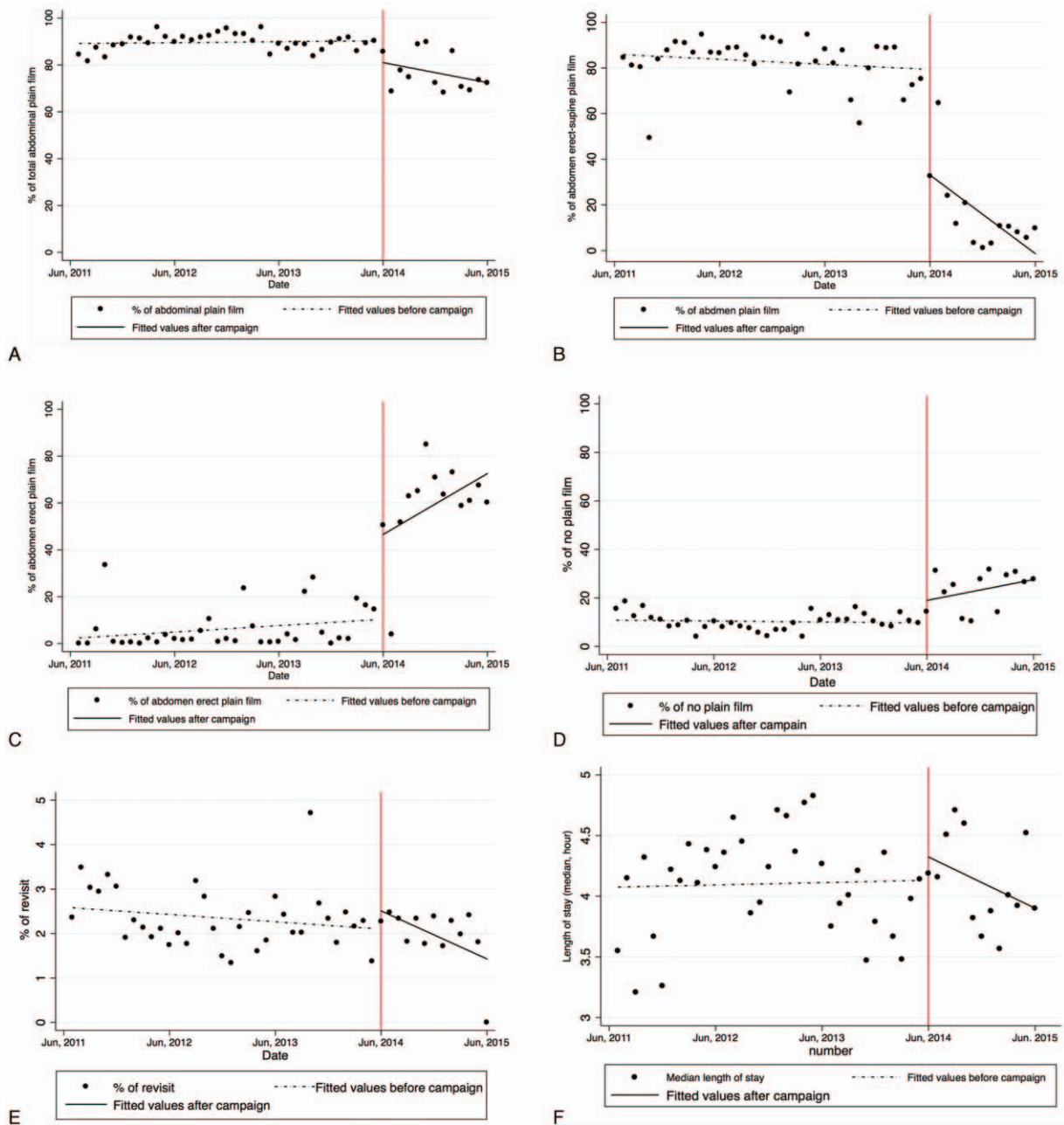
	Before campaign	After campaign	P
Total no. of patient	10,729	3515	
Age, y, mean (95% CI)	7.32 (7.25–7.40)	7.96 (7.83–8.10)	<0.001
Male sex, N (%)	6001 (56)	1978 (56)	0.72
LOS in PED, h, mean (95% CI)	4.11 (3.97–4.24)	4.11 (3.86–4.35)	0.99
	<b>Number (%)</b>	<b>Number (%)</b>	
Patient according to CC			
Abdominal pain	4854 (45)	1580 (45)	0.82
Nausea	201 (2)	67 (2)	
Vomiting	3264 (30)	1084 (31)	
Diarrhea	2350 (22)	772 (22)	
Constipation	60 (1)	12 (0)	
Total APF <sup>*</sup>	9647 (90)	2710 (77)	<0.001
AES <sup>†</sup>	8959 (84)	501 (14)	<0.001
AE <sup>†</sup>	605 (6)	2166 (62)	<0.001
AS <sup>†</sup>	83 (1)	43 (1)	0.002
None <sup>†</sup>	1082 (10)	805 (23)	<0.001
Return visit <sup>‡</sup>	220 (2)	56 (2)	0.10
AES <sup>‡</sup>	192 (2)	11 (2)	0.87
AE <sup>‡</sup>	1 (1)	38 (2)	0.001
AS <sup>‡</sup>	0 (0)	0 (0)	—
None <sup>‡</sup>	27 (2)	7 (1)	0.008

AE=abdominal erect plain film, AES=abdominal erect-supine plain film, APF=abdominal plain film, AS=abdominal supine plain film, CC=chief complaint, CI=confidence interval, LOS=length of stay, PED=pediatric emergency department.

\* Compared to the total number of patients.

† Compared to the total number of abdominal plain film.

‡ Compared to the number of each type of abdominal plain film.



**Figure 1.** The slopes representing the trend changes about abdominal plain films, return visits, and length of stay in the pediatric emergency department. (A) Total abdominal plain film ratio, (B) abdominal erect-supine plain film ratio, (C) abdominal erect plain film ratio, (D) none plain film ratio, (E) return visits to the pediatric emergency department ratio, and (F) length of stay in the pediatric emergency department.

**Table 3**  
**Piecewise regression of the differences of slopes and ratio of abdominal plain films before and after the campaign.**

	Slope before the campaign	Slope after the campaign	Difference of slope*	SE	P	95% CI
Total APF	0.03	-0.71	-0.75	0.38	0.056	-1.51 to -0.02
AES	-0.19	-2.86	-2.68	0.87	0.004	-4.43 to -0.93
AE	0.23	2.17	1.94	0.89	0.035	0.15 to 3.73
None	-0.03	0.71	0.75	0.38	0.056	-0.02 to 1.51
	Predicted % on June 1, 2014	Actual % on June 1, 2014	Difference of %†	SE	P	95% CI
Total APF	90.32	81.01	-9.31	3.14	0.005	-15.64 to -2.98
AES	79.34	33.05	-46.30	7.17	<0.001	-60.75 to -31.84
AE*	10.35	46.55	36.20	7.36	<0.001	21.38 to 51.02
None*	9.68	18.99	9.31	3.14	0.005	2.98 to 15.64

AE=abdominal erect plain film, AES=abdominal erect-supine plain film, APF=abdominal plain film, CI=confidence interval, SE=standard error.

\* Compared to the predicted slope of abdominal plain film ratio if there had not been the reducing radiation to children campaign at June 1, 2014.

† Percentage to total APF.

**Table 4****Adverse events and further evaluations in the return visit cases before and after the campaign.**

	Before the campaign (June 1, 2011 to May 30, 2014), Number (%)	After the campaign (June 1, 2014 to May 30, 2015), Number (%)	P
Total	220 (2)	56 (2)	0.10
Adverse events			
Admission	28 (13)	7 (13)	1.00
Operation	3 (1)	1 (2)	1.00
Further evaluations			
Added APF	98 (45)	12 (21)	0.002
Ultrasound	30 (14)	14 (6)	0.063
Abdomen CT	12 (5)	3 (5)	1.00

APF=abdominal plain film, CT=computer tomography.

**Table 5****Piecewise regression of the length of stay and return visits rate as patient care indicators before and after the campaign.**

	Slope before the campaign	Slope after the campaign	Difference of slope*	SE	P	95% CI
LOS, h	0.002	-0.352	-0.368	0.03	0.24	-0.099 to 0.026
Revisit (number)	-0.01	-0.09	-0.08	0.05	0.13	-0.18 to 0.02

	Predicted value	Actual value	Difference	SE	P	95% CI
LOS, h	4.13	4.32	0.19	0.26	0.46	-0.33 to 0.71
Revisit (number)	2.10	2.51	4.08	0.41	0.33	-0.42 to 1.24

CI=confidence interval, LOS=length of stay (median), SE=standard error.

\* Compared to the period before the campaign.

Accordingly, we excluded from our study patients with a history of abdominal surgery and those who required hospitalization for poor clinical conditions.

In a study of 164 children seen in an emergency department setting, the use of radiographs could be reduced in at least 30% of cases without compromising patient care. In this previous study, the most common reason for performing a radiographic series was suspected bowel obstruction (28%); however, the results were positive in only 6.5% of cases. Plain radiographs are occasionally useful for demonstrating abnormal calcifications in the abdomen.<sup>[19]</sup> Unfortunately, only 13% to 22% of children with appendicitis demonstrate a calcified appendicolith on plain film. The plain film findings associated with appendicitis are otherwise disappointingly insensitive and nonspecific. Therefore, it is generally recommended that the use of plain film radiography should be carefully approached as a screening procedure for nonspecific abdominal pain.<sup>[1-4,8]</sup> However, many emergency physicians still perform APF X-rays as a screening tool for the evaluation of patients with nonspecific abdominal symptoms because of difficulties in deciding quickly whether to perform abdominal X-rays. In these situations, our pediatric emergency physicians and residents regularly use APF, AE, or AS X-ray. If the need for abdominal X-ray is certain and there is no other option in a real emergency department setting, we believe that AE is a sufficient screening tool for patient evaluation. Actually, our study demonstrates that the substitution of AE for 2 traditional APF (AES) views did not increase the rate of complications (e.g., RV rate, adverse events in RVs, and LOS), a measure of patient safety.

In recent years, there has been increasing awareness of radiation exposure and the associated potential cancer risk.<sup>[5]</sup> Since 2000, related reports have discussed this issue and support the idea that increased radiation exposure leads to an increased risk of neoplasm formation, especially in pediatric populations.<sup>[10]</sup> One APF X-ray yields a radiation dose of 0.7 mSv, or a 35-fold greater radiation dose than that received during a chest X-ray examination (0.02 mSv).<sup>[16-20,21]</sup> Children feature more

active cellular division and a smaller body area, which leads to a greater radiation dosage accumulation.<sup>[22,23]</sup> Although there is no scientifically proven link between cancer risks and low-dose radiation exposure from medical imaging, the linear no-threshold model based on data from survivors of atomic bombs and nuclear accidents and the early use of X-rays has been accepted to ensure the highest standard of patient safety.<sup>[23]</sup> Our campaign was attempted in this regard, and the final purpose of this campaign is to reduce medical hazards caused by healthcare providers' misconceptions of radiological studies.

This study had several limitations. First, this was before-and-after study conducted at a single center with historical controls, and therefore our results cannot be generalized to other institutions. Second, the statistical model might not have captured the ceiling effect or attenuation of the increasing preintervention trajectory; accordingly, the modeled net effect might be greater than would be clinically observed. In addition, the time period of only 1 year after the campaign might limit the significance and validity of the piecewise regression analysis and the long-term behavioral changes was not addressed in prescribing patterns for physicians ordering the radiographs.

In conclusion, the implementation of our campaign to reduce radiation exposure in children in the PED resulted in a successful reduction of in the rate of APF X-ray performance, with no changes in patient safety and management processes, as determined by the RV rate and LOS in emergency department.

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