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Research

Variation in low-value radiograph use for children in the emergency department: a cross-sectional study of administrative databases

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Abstract

Background: Radiograph use contributes to low-value care for children in emergency departments (EDs), but little is known about systemic factors associated with their use. This study compares low-value radiograph use across ED settings by hospital type, pediatric volumes and physician specialty.

Methods: This is a cross-sectional study of routinely collected administrative data. We included children (age 0–18 yr) discharged from EDs in Ontario, Canada, between 2010 and 2019 with diagnoses of bronchiolitis, asthma, abdominal pain and constipation. Multiple clinical practice guidelines recommend against routine radiograph use in these conditions. Logistic regression evaluated odds of low-value radiograph by ED setting (pediatric academic [referent], adult academic, community with or without pediatric consultation services), pediatric volume and physician specialty (pediatric emergency medicine [PEM, referent], emergency medicine [EM], family medicine with EM training, pediatrics, family medicine), adjusting for demographic, clinical and provider characteristics. We used generalized estimating equations to account for clustering by ED.

Results: Of the total 9862787 eligible pediatric ED discharges in Ontario, 60914 children had bronchiolitis, 141921 asthma, 333332 abdominal pain and 110514 constipation; 26.0% received low-value radiographs. Compared with pediatric EDs and PEM physicians (referents), patients with bronchiolitis were most likely to have a chest radiograph in adult academic EDs (adjusted odds ratio [OR] 5.1 [95% confidence interval (CI) 4.6–5.6]) and by family physicians with EM training (adjusted OR 4.8 [95% CI 4.5–5.1]). Patients with asthma were more likely to have a chest radiograph in adult academic EDs (adjusted OR 3.0 [95% CI 2.8–3.2]) and by EM physicians (adjusted OR 2.8 [95% CI 2.6–3.0]). Patients with abdominal pain and constipation were more likely to have abdominal radiographs in community hospitals with pediatric consultation (adjusted OR 1.6 [95% CI 1.6–1.7] and 2.3 [95% CI 2.3–2.4], respectively) and by family physicians with EM training (adjusted OR 1.6 [95% CI 1.6–1.7] and 2.1 [95% CI 2.0–2.2], respectively).

Interpretation: Over the decade-long study period, low-value radiograph use was frequent for children with 4 common conditions seen in Ontario EDs. Quality improvement initiatives aimed at reducing unnecessary radiographs in children should focus on EM physicians practising in EDs that primarily treat adult patients.

"Low-value care" describes medical interventions that do not have additional benefit when compared with a less costly alternative.[1,2] Decreasing "low-value care" has been identified as a priority to reduce wait times, patient exposure to harm and anxiety, and unnecessary costs.[1,2] Diagnostic imaging is a major contributor to low-value care in the emergency department (ED),[3–5] and accounts for 6 of 10 Choosing Wisely recommendations for emergency physicians in Canada (https://choosingwiselycanada.org/recommendation/emergency-medicine/). Low-value diagnostic imaging is a particularly important issue for pediatric patients, who are at increased risk of harm because of their increased susceptibility to ionizing radiation[6] and the harms related to unnecessary treatments associated with diagnostic imaging use.[7,8] One particular area for improvement is the use of low-value radiographs for common pediatric conditions that present to the ED. Multiple clinical practice guidelines recommend against routine radiograph use for bronchiolitis,[9–15] asthma,[12,13,16–18] abdominal

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pain[13,19] and constipation.[7,20–22] For these conditions, refraining from using radiographs would represent higher-value care (Appendix 1, Supplemental Table 1, available at www.cmajopen.ca/content/10/4/E889/suppl/DC1). Together, these 4 diagnoses represent 15%–20% of all pediatric ED visits.[23–26]

Practice variation that cannot be explained by patient illness or preferences is labelled as unwarranted and leads to variations in low-value care.[27] Unwarranted practice variation exists in the emergency care of children,[27,28] and differences in ED settings are important contributors to this phenomenon.[4,27–32] Specifically, EDs with pediatric designation provide higher-value care and are associated with improved outcomes for respiratory emergencies in children.[3,33–37] Institutions with higher pediatric patient volumes are associated with better adherence to resuscitation guidelines in the ED setting.[38–40] Practice variation in the emergency care of children is also attributed to physician characteristics, with pediatric emergency specialty training leading to higher-value care when compared with other physician specialties.[33,40–42] Although some studies have focused on radiograph use in the ED,[3,34,35,37,42,43] few have looked across multiple diagnoses or ED settings to identify predictors of practice variation.[33,41,44] Identifying setting- and provider-specific characteristics contributing to low-value radiograph use will inform the development of quality improvement (QI) interventions, known to be effective in improving pediatric care,[45–49] to decrease unnecessary radiographs. To address this, we aimed to compare radiograph use between ED settings (hospital type and pediatric volume) and ED physician specialties. We hypothesized that there would be substantial practice variation between settings and providers, with pediatric institutions and providers having lower rates of radiograph use.

Methods

Study design

This was a cross-sectional study using routinely collected administrative data of all pediatric (age 0–18 yr) unscheduled ED visits to any hospital in the province of Ontario, Canada, during the 2010–2019 calendar years. This study followed the Reporting of Studies Conducted Using Observational Routinely-collected Data (RECORD) statement and checklist.[50]

Data sources

We obtained data from linked population-based administrative health databases housed at ICES, which uses unique encoded identifiers to link an individual's records across databases over time while preserving anonymity. Databases used included the National Ambulatory Care Reporting System (NACRS), the Ontario Health Insurance Plan database, the Canadian Institute for Health Information's Discharge Abstract Database (CIHI-DAD), the Ontario Registered Persons Database (RPDB), the Citizenship and Immigration Canada Permanent Resident Database (CIC), the ICES Physician Database (IPDB), the Ontario Institutions Database (INST), the Ontario Asthma Data set (ASTHMA) and the Postal Code Conversion File (Appendix 1, Supplemental Tables 2 and 3; Appendix 2, available at www.cmajopen.ca/content/10/4/E889/suppl/DC1).

Setting and population

This population-based cohort study used linked administrative health data from Ontario, Canada, where health care, including all ED care, is provided through a public health insurance plan.

Using Ontario's definition of a pediatric patient, we selected all visits by children aged 0–18 years discharged from the ED with the following diagnoses: bronchiolitis (chest radiograph),[9–15] asthma (chest radiograph),[12,13,16–18] abdominal pain (abdominal radiograph)[13,19] and constipation (abdominal radiograph).[7,20–22] We chose these conditions for their high prevalence among pediatric emergency visits and for the strong supporting evidence recommending against routine radiograph use for these conditions (Appendix 1, Supplemental Tables 1 and 2).

We excluded patients who were admitted to hospital, transferred from or to another facility or who died in the ED, to focus on a low-risk population of patients less likely to have one of the rare indications for radiograph for these conditions.

Variables

For each index ED visit, we collected patient demographics (age, sex, income quintile, rurality, immigration or refugee status, presence of a chronic complex condition[51]) and characteristics of the ED visit, including Canadian Triage Acuity Scale score (CTAS; a validated triage score used to predict illness severity for pediatric patients),[52–55] time and day of presentation. We collected characteristics related to the physician (sex, domestic v. foreign training, years in practice, specialty), and the hospital (academic status, pediatric patient volumes). We collected these variables to account for their known and possible impact on resource utilization (Appendix 1, Supplemental Table 2).

Exposures

We defined hospital type using the hospital designation reported in the INST database, and separated them out into pediatric academic hospitals, adult academic hospitals and community hospitals with and without consultant pediatricians. We defined pediatric consultation availability based on the frequency distribution of pediatric consultations at each hospital; those with fewer than 2 consultations per week in the ED were presumed not to have regular access to pediatric consultation services. This cut-off was chosen by team consensus, as there are no recognized standards for measuring access to pediatric services at nonpediatric hospitals. We separated nonpediatric hospitals as described, to account for substantial differences in practice, resources and patient populations between adult academic and community hospitals.

We also defined ED setting by pediatric volumes, using the average annual hospital pediatric ED visit volumes over the study period, and dividing the volumes into tertiles (low, medium, high).

We identified the ED physician through ED billing codes for services rendered during, or within 24 hours of, the index ED visit. We identified specialty training for each physician as documented in the IPDB database. To account for instances where more than 1 ED physician was associated with the index ED visit, we created a hierarchy based on the subspecialties listed in the IPDB. We used the hierarchy to select the physician specialty most likely to be providing care within an ED setting, and prioritized specialties in the following order: pediatric emergency medicine (PEM), emergency medicine (EM), family medicine with additional EM training, pediatrics, family medicine and other specialties. For example, if a patient was seen by both a family physician with EM training and a pediatrician, it was assumed that the family physician with EM training saw the patient first and ordered the radiograph and pediatric consult.

Outcomes

We deemed patients to have received low-value care if they received a radiograph for the 4 conditions above, for which radiographs are not indicated. We identified radiograph use through emergency radiology billing codes used during, or within 24 hours of, the index ED visit. We assessed whether patients discharged without imaging had deleterious outcomes by examining the rates of ED return visits, hospital admission, intensive care unit (ICU) admission, or death within 7 days after the index visit (Appendix 1, Supplemental Tables 2 and 3).

Statistical analysis

We fitted a logistic regression model, adjusting for the correlation within 2 levels of non-nested clusters (ED institution and patient) using generalized estimating equations, to evaluate the odds of receiving a radiograph for each condition by hospital characteristics (hospital type and pediatric volumes)

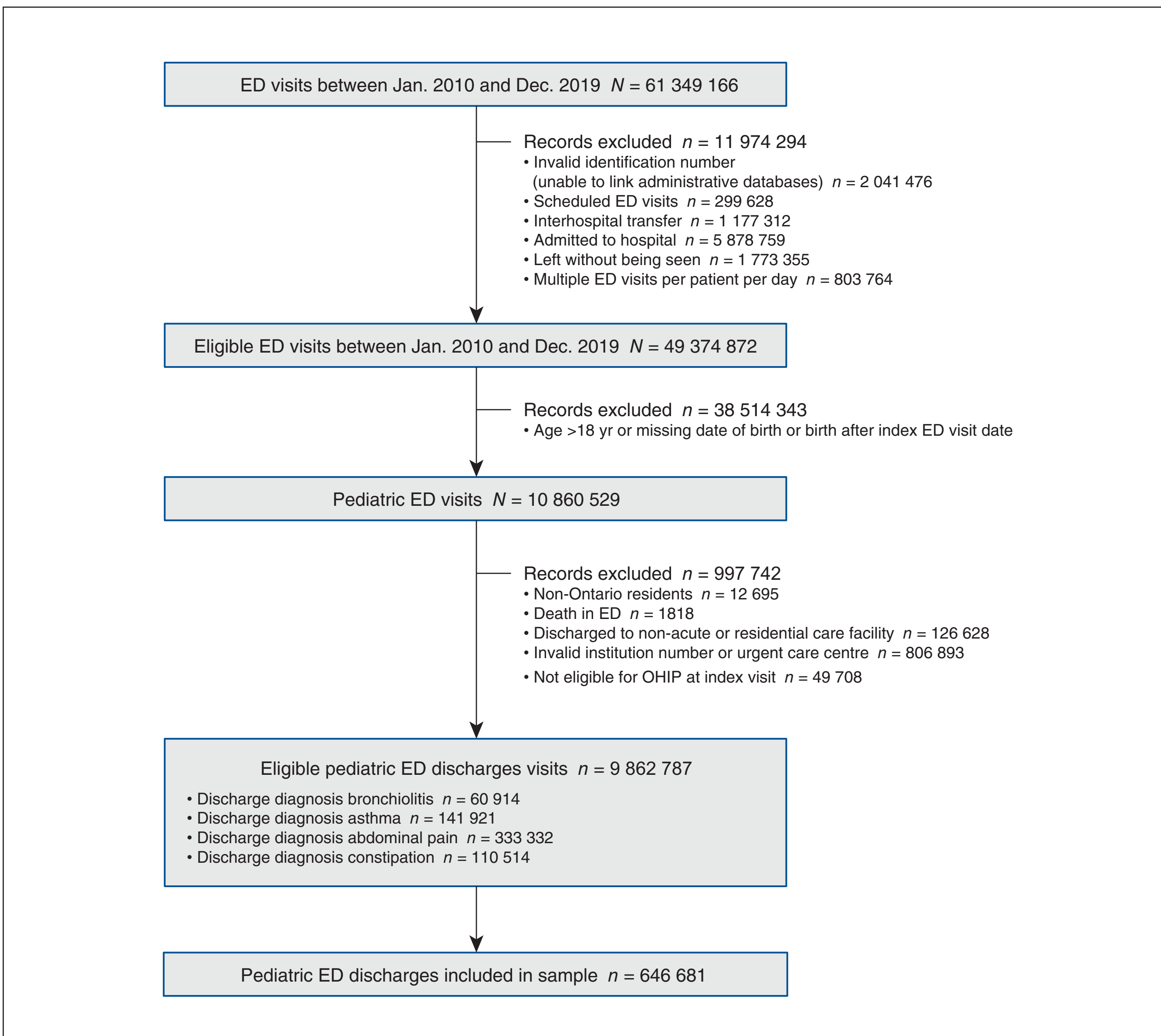

Figure 1: Flow diagram of unscheduled pediatric emergency department discharges at Ontario hospitals between 2010 and 2019. Note: ED = emergency department, OHIP = Ontario Health Insurance Plan.

Table 1 (part 1 of 2): Characteristics of unscheduled pediatric emergency department discharges in Ontario hospitals between 2010 and 2019

	No. (%)*			
Characteristic	Patients with bronchiolitis *n* = 60 914	Patients with asthma *n* = 141 921	Patients with abdominal pain *n* = 333 332	Patients with constipation *n* = 110 514
Clinical characteristics				
Age, yr, mean ± SD	0.7 ± 1.6	7.4 ± 5.2	11.1 ± 5.1	6.4 ± 5.2
Sex, female	23 305 (38.3)	53 999 (38.0)	199 573 (59.9)	58 142 (52.6)
Neighbourhood income quintile†				
1 (low)	15 170 (24.9)	34 622 (24.4)	69 313 (20.8)	26 020 (23.5)
2	11 801 (19.4)	28 750 (20.3)	63 696 (19.1)	21 958 (19.9)
3	12 235 (20.1)	28 054 (19.8)	66 582 (20.0)	22 265 (20.1)
4	12 428 (20.4)	26 840 (18.9)	69 760 (20.9)	22 176 (20.1)
5 (high)	8993 (14.8)	23 043 (16.2)	62 896 (18.9)	17 666 (16.0)
Rurality†				
Rural	8813 (14.5)	25 746 (18.1)	48 779 (14.6)	18 235 (16.5)
Immigrant or refugee status	226 (0.4)	2938 (2.1)	18 887 (5.7)	3450 (3.1)
Chronic complex condition	1544 (2.5)	1978 (1.4)	6837 (2.1)	2524 (2.3)
CTAS score†				
1	711 (1.2)	2119 (1.5)	192 (0.1)	71 (0.1)
2	21 678 (35.6)	44 856 (31.6)	42 427 (12.7)	10 035 (9.1)
3	30 865 (50.7)	66 914 (47.1)	224 568 (67.4)	62 584 (56.6)
4	7096 (11.6)	25 407 (17.9)	60 726 (18.2)	33 745 (30.5)
5	480 (0.8)	2358 (1.7)	4921 (1.5)	3884 (3.5)
Time of ED presentation				
Mon.–Fri.: 08:01 to 16:00	17 995 (29.5)	36 232 (25.5)	102 679 (30.8)	33 634 (30.4)
Mon.–Fri.: 16:01 to 24:00 or Sat./Sun.: 08:01 to 16:00	25 479 (41.8)	56 697 (39.9)	135 920 (40.8)	46 643 (42.2)
Mon.–Fri.: 00:01 to 08:00 or Sat./Sun.: 16:01 to 08:00	15 052 (24.7)	44 476 (31.3)	87 294 (26.2)	27 166 (24.6)
Holidays	2388 (3.9)	4,516 (3.2)	7439 (2.2)	3071 (2.0)
ED length of visit, h				
< 2	18 030 (29.6)	49 204 (34.7)	82 021 (24.6)	37 380 (33.8)
2–4	26 800 (44.0)	57 395 (40.4)	132 409 (24.6)	47 664 (43.1)
4–6	11 125 (18.3)	23 786 (16.8)	74 247 (22.3)	17 909 (16.2)
≥ 6	4890 (8.0)	11 247 (7.9)	43 785 (13.1)	7278 (6.6)
Physician characteristics				
Physician specialty†				
PEM	9895 (16.2)	16 837 (11.9)	25 017 (7.5)	13 487 (12.2)
EM	3267 (5.4)	7568 (5.3)	25 995 (7.8)	6376 (5.8)
FP + EM	21 224 (34.8)	52 564 (37.0)	149 865 (45.0)	36 239 (32.8)
Pediatrics	8810 (14.5)	13 075 (9.2)	21 077 (6.3)	14 251 (12.9)
GP or FP	14 809 (24.3)	45 503 (32.1)	97 388 (29.2)	34 289 (31.0)
Other‡	1280 (2.1)	2197 (1.5)	7554 (2.3)	3036 (2.7)
Sex†				
Female	19 635 (32.2)	38 876 (27.4)	90 286 (27.1)	34 580 (31.3)
Age, yr, mean ± SD	44.3 ± 9.0	44.7 ± 9.5	43.9 ± 9.2	44.5 ± 9.4
Years in practice† mean ± SD	15.9 ± 10.2	16.7 ± 10.7	15.7 ± 10.3	16.1 ± 10.5
International medical graduate†	8914 (14.6)	17 914 (12.6)	41 335 (29.8)	35 166 (31.8)

Table 1 (part 2 of 2): Characteristics of unscheduled pediatric emergency department discharges in Ontario hospitals between 2010 and 2019

Characteristic	No. (%)*			
	Patients with bronchiolitis *n* = 60 914	Patients with asthma *n* = 141 921	Patients with abdominal pain *n* = 333 332	Patients with constipation *n* = 110 514
Hospital characteristics				
Hospital type				
Pediatric academic hospitals, *n* = 4	19 612 (32.2)	31 430 (22.1)	54 017 (16.2)	32 592 (29.5)
Academic hospitals, *n* = 18	1927 (3.2)	5368 (3.8)	20 147 (6.0)	4454 (4.0)
Community hospitals with pediatric consultation, *n* = 52	27 806 (45.6)	65 212 (45.9)	183 374 (55.0)	46 131 (41.7)
All other community hospitals, *n* = 107	11 569 (19.0)	39 911 (28.1)	75 794 (22.7)	27 337 (24.7)
ED volume				
Low	2056 (3.4)	9777 (6.9)	20 357 (6.1)	6070 (5.5)
Medium	8391 (13.8)	26 355 (18.6)	55 458 (16.6)	19 061 (17.2)
High	50 467 (82.8)	105 789 (74.5)	257 517 (77.3)	85 383 (77.3)

Note: CTAS = Canadian Triage Acuity Scale, ED = emergency department, EM = emergency medicine, FP = family practice, GP = general practice, PEM = pediatric emergency medicine, SD = standard deviation.
*Unless otherwise specified.
†Missing data were limited to the following variables: neighbourhood income quintile (*n* = 2413 [0.4%]), rurality (*n* = 831 [0.1%]), CTAS score (*n* = 1054 [0.3%]), physician specialty (*n* = 15 078 [2.3%]), physician sex (*n* = 15 078 [2.3%]) and physician years in practice (*n* = 15 092 [2.3%]), and physician domestic v. international training (*n* = 77 154 [11.9%]).
‡Other physician specialties included critical care medicine, psychiatry, internal medicine, anesthesiology, orthopedic surgery, cardiology, nuclear medicine, otolaryngology, neonatal medicine, general surgery and 44 others.

and by physician specialty.[56,57] We performed a complete case analysis and assumed an exchangeable correlation matrix. In our models, we adjusted for patient demographics (age, sex, household income quintile, immigration status, and presence of complex chronic conditions), ED visit characteristics (CTAS score, time and day of ED presentation), and physician characteristics (sex, domestic or foreign training, and years in practice). Each exposure was modelled separately owing to collinearity between exposures.

Because children are more likely to receive imaging when they have underlying health issues or with repeated ED visits, which may be indicative of diagnostic uncertainty, sensitivity analyses were conducted excluding patients with complex chronic conditions and excluding any return visits within 72 hours of an index ED visit. We also performed a sensitivity analysis excluding lowest-volume hospitals, which may have limited resources, to ensure that imaging availability did not affect our results.

We used standardized risk differences to evaluate comparisons in the rates of balancing measures between patients with and without imaging for each diagnosis. We used a standardized difference of 0.1 as a cut-off to denote significant imbalances between groups.[58] We calculated yearly radiograph usage rates for each diagnosis to assess for trends. We completed the analyses using SAS version 9.4 (SAS Institute, Inc).

Ethics approval

We obtained a privacy impact assessment and approval from ICES' Privacy & Legal Office, and the study was deemed exempt from research ethics board approval at SickKids, as the analysis was conducted using administrative data for the purposes of health system evaluation.

Results

During the study period, there were 9 862 787 eligible pediatric ED discharges in Ontario. Of these, we included 646 681 ED discharges for analysis: 60 914 for bronchiolitis, 141 921 for asthma, 333 332 for abdominal pain and 110 514 for constipation (Figure 1). The mean age was 8 years (standard deviation 6.1), and 335 019 (51.8%) participants were female. In this cohort, 12 883 (2.0%) patients had a complex chronic condition, 25 501 (3.9%) had immigrant or refugee status, and 101 573 (15.7%) lived in a rural setting (Table 1).

Emergency department visits involved 18 418 physicians and were distributed across 181 hospitals: 4 pediatric academic hospitals (137 651 visits [21.3%]), 18 adult academic hospitals (31 896 visits [4.9%]), 52 community hospitals with pediatrics (322 523 visits [49.9%]), and 107 community hospitals without pediatrics (154 611 visits [23.9%]).

The overall rate of radiograph use in our cohort was 26.0%, and ranged from 18.0% for children discharged with abdominal pain to 27.0% for asthma, 37.0% for bronchiolitis and 41.0% for constipation.

Radiograph use by hospital type

Patients discharged with bronchiolitis and asthma were more likely to have a chest radiograph when seen in nonpediatric

EDs than in pediatric EDs (the referent), with highest use in adult academic EDs (adjusted odds ratio [OR] 5.1 [95% confidence interval (CI) 4.6–5.6] for bronchiolitis and 3.0 [2.8–3.2] for asthma). Similarly, children discharged with abdominal pain and constipation were more likely to have an abdominal radiograph when seen in nonpediatric EDs, with highest use at community EDs with pediatric support (adjusted OR 1.6 [95% CI 1.6–1.7] for abdominal pain and 2.3 [95% CI 2.3–2.4] for constipation) (Figure 2).

Radiograph use by pediatric volumes

Radiograph use was least prevalent among EDs with low pediatric volumes across all discharge diagnoses. Among patients discharged with bronchiolitis and asthma, compared with EDs in the highest volume tertile (the referent), radiograph use was lowest in EDs with low pediatric volumes (adjusted OR 0.66 [95% CI 0.59–0.73] for bronchiolitis and 0.57 [95% CI 0.53–0.60] for asthma). For patients discharged with abdominal pain and constipation, radiograph use was also lowest among EDs with low pediatric volumes (adjusted OR 0.49 [95% CI 0.47–0.52] for abdominal pain and 0.39 [95% CI 0.37–0.42] for constipation) (Figure 3).

Radiograph use by physician specialty

Children discharged with bronchiolitis were more likely to have a chest radiograph when seen by non-PEM physicians than by PEM physicians (the referent), with highest use by family physicians with EM training (adjusted OR 4.8 [95% CI 4.5–5.2]). Patients discharged with asthma were more likely to have a chest radiograph when seen by non-PEM physicians, with highest use among EM specialists (adjusted OR 2.8 [95% CI 2.6–3.0]). Similarly, patients with abdominal pain and constipation were more likely to have abdominal radiographs when seen by nonpediatric physicians, with

Low-value DI modality	*n*/*N* (%)	Adjusted OR (95% CI)*†
Chest radiograph for bronchiolitis		
Pediatric academic	3230/19 612 (16.5)	1.0 (ref.)
Adult academic	1004/1927 (52.4)	5.1 (4.6–5.6)
Community with pediatrics	14 398/27 806 (51.8)	4.8 (4.6–5.1)
Community without pediatrics	4166/11 569 (36.0)	2.9 (2.7–3.0)
Chest radiograph for asthma		
Pediatric academic	5277/31 430 (16.8)	1.0 (ref.)
Adult academic	1984/5368 (37.0)	3.0 (2.8–3.2)
Community with pediatrics	21 949/65 212 (33.7)	2.6 (2.5–2.7)
Community without pediatrics	8939/39 911 (22.4)	1.6 (1.6–1.7)
Abdominal radiograph for abdominal pain		
Pediatric academic	7442/54 017 (13.8)	1.0 (ref.)
Adult academic	3115/20 147 (15.5)	1.3 (1.2–1.3)
Community with pediatrics	38 013/183 374 (20.7)	1.6 (1.6–1.7)
Community without pediatrics	12 631/75 794 (16.7)	1.4 (1.3–1.4)
Abdominal radiograph for constipation		
Pediatric academic	9892/32 592 (30.4)	1.0 (ref.)
Adult academic	1977/4454 (44.4)	1.6 (1.5–1.7)
Community with pediatrics	23 400/46 131 (50.7)	2.3 (2.3–2.4)
Community without pediatrics	10 411/27 337 (38.1)	1.4 (1.3–1.4)

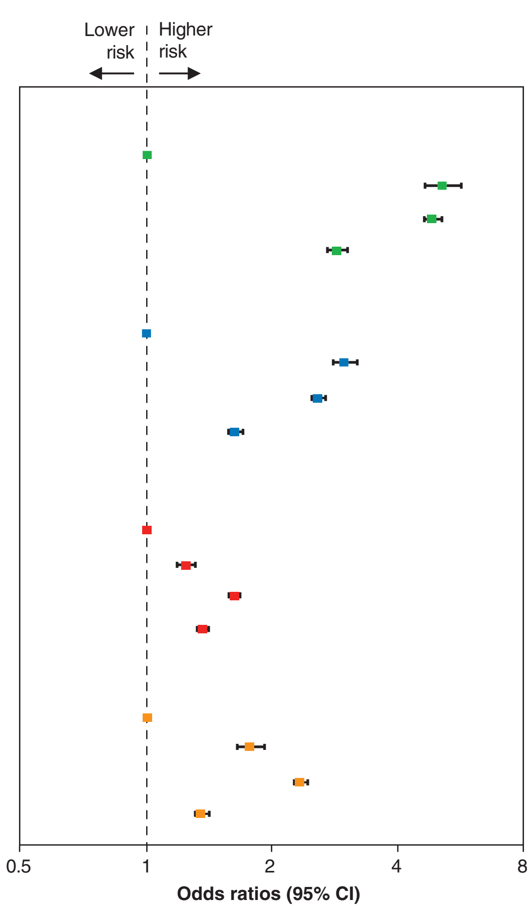

Figure 2: Pediatric radiograph use by hospital type at Ontario emergency departments between 2010 and 2019. *We performed analyses using a complete case analysis with the following observation counts (*n* [%]) excluded owing to missing data: bronchiolitis (1955 observations [3.2%]), asthma (4971 observations [3.5%]), abdominal pain (7774 observations [2.3%]), constipation (3368 observations [3.0%]). †All models were adjusted for patient age, sex, income quintile, immigrant or refugee status, complex chronic conditions, Canadian Triage Acuity Scale score, time of presentation, physician sex, physician years in practice and physician training background (domestic v. international). Note: CI = confidence interval, DI = diagnostic imaging, OR = odds ratio, ref. = reference.

highest use among family physicians with EM training (adjusted OR 1.6 [95% CI 1.6–1.7] and 2.1 [95% CI 2.0–2.2], respectively) (Figure 4).

Trends in radiograph use over time

Overall annual radiograph use was relatively stable during our study period, from 27.8% in 2010 to 24.8% in 2019. Annual radiograph use decreased for bronchiolitis (from 43.3% in 2010 to 35.0% in 2019), abdominal pain (19.9%–16.9%) and constipation (44.4%–39.5%), and increased for asthma (26.8%–29.1%) (Appendix 3, Supplemental Figure 1, available at www.cmajopen.ca/content/10/4/E889/suppl/DC1).

Additional analyses

Differences in radiograph use persisted when excluding patients with chronic complex conditions, return ED visits and lowest pediatric volume hospitals (Appendix 1, Supplemental Tables 4–6).

There were no differences in return visits, hospital admission, ICU admission or death between patients who received imaging or not (Table 2).

Interpretation

We found that radiograph use was common among children discharged from Ontario EDs with 4 common pediatric conditions. We also found important differences in radiograph use across ED settings and physician specialties. Radiographs were consistently less likely to be used in pediatric academic centres and by PEM-trained physicians. Hospital pediatric volume did not explain this finding. This study adds to a growing body of literature describing low-value care and its contributors by demonstrating variations in low-value radiograph use consistent across multiple pediatric conditions, and along the spectrum of ED settings and physician specialties that manage pediatric ED patients.

Our findings are consistent with reports of higher radiograph use among children who receive a bronchiolitis, asthma and croup diagnosis and present at nonpediatric EDs.[33,34,36] Many differences exist between general EDs and pediatric EDs, which may explain this finding. Continuing medical education and QI initiatives in EDs predominantly serving adult populations are likely focused on adult issues, and less

Low-value DI modality	*n/N* (%)	Adjusted OR (95% CI)*†
Chest radiograph for bronchiolitis		
High volume	19 280/50 467 (38.2)	1.0 (ref.)
Medium volume	2969/8391 (35.4)	0.88 (0.84–0.93)
Low volume	549/2056 (26.7)	0.66 (0.59–0.73)
Chest radiograph for asthma		
High volume	30 057/105 789 (28.4)	1.0 (ref.)
Medium volume	6507/26 355 (24.7)	0.88 (0.85–0.91)
Low volume	1585/9777 (16.2)	0.47 (0.53–0.60)
Abdominal radiograph for abdominal pain		
High volume	49 475/257 517 (19.2)	1.0 (ref.)
Medium volume	9885/55 458 (17.8)	0.97 (0.94–0.99)
Low volume	1841/20 357 (9.0)	0.49 (0.47–0.52)
Abdominal radiograph for constipation		
High volume	36 469/85 383 (42.7)	1.0 (ref.)
Medium volume	7770/19 061 (40.8)	0.85 (0.82–0.88)
Low volume	1441/6070 (23.7)	0.39 (0.37–0.42)

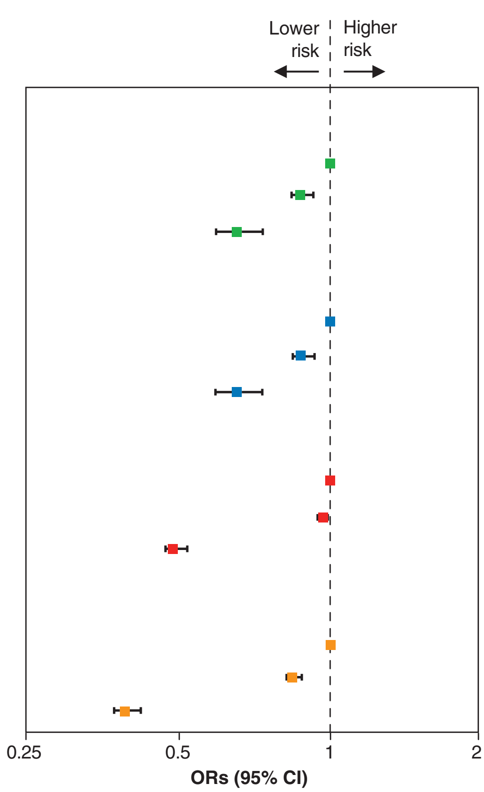

Figure 3: Pediatric radiograph use by pediatric volumes at Ontario emergency departments between 2010 and 2019. *We performed analyses using a complete case analysis with the following observation counts (*n* [%]) excluded owing to missing data: bronchiolitis (1955 observations [3.2%]), asthma (4971 observations [3.5%]), abdominal pain (7774 observations [2.3%]), constipation (3368 observations [3.0%]). †All models were adjusted for patient age, sex, income quintile, immigrant or refugee status, complex chronic conditions, Canadian Triage Acuity Scale score, time of presentation, physician sex, physician years in practice and physician training background (domestic v. international). Note: CI = confidence interval, DI = diagnostic imaging, OR = odds ratio, ref. = reference.

Low-value DI modality	*n/N* (%)	Adjusted OR (95% CI)*†
Chest radiograph for bronchiolitis		
Pediatric emergency medicine	1592/9895 (16.1)	1.0 (ref.)
Emergency medicine	1307/3267 (40.0)	3.3 (3.0–3.6)
Family medicine + emergency medicine	10 731/21 224 (50.6)	4.8 (4.5–5.2)
Pediatrics	2277/8810 (25.8)	1.7 (1.6–1.9)
Family medicine	6052/8757 (40.9)	3.5 (3.2–3.7)
Other†	813/1280 (63.5)	9.1 (8.0–10.3)
Chest radiograph for asthma		
Pediatric emergency medicine	2637/14 200 (15.7)	1.0 (ref.)
Emergency medicine	2491/5077 (32.9)	2.8 (2.6–3.0)
Family medicine + emergency medicine	16 772/52 564 (31.9)	2.7 (2.6–2.9)
Pediatrics	3025/13 075 (23.1)	1.7 (1.6–1.8)
Family medicine	11 819/45 503 (26.0)	2.2 (2.1–2.3)
Other†	1318/2197 (60.0)	8.9 (8.0–10.0)
Abdominal radiograph for abdominal pain		
Pediatric emergency medicine	3459/25 017 (13.8)	1.0 (ref.)
Emergency medicine	4079/25 995 (15.7)	1.2 (1.2–1.3)
Family medicine + emergency medicine	31 745/149 865 (21.2)	1.6 (1.6–1.7)
Pediatrics	3055/21 077 (14.5)	1.0 (0.9–1.0)
Family medicine	16 720/97 388 (17.2)	1.3 (1.3–1.4)
Other†	2012/7554 (26.6)	2.3 (2.2–2.5)
Abdominal radiograph for constipation		
Pediatric emergency medicine	4161/13 487 (30.9)	1.0 (ref.)
Emergency medicine	2830/6376 (44.4)	1.7 (1.6–1.8)
Family medicine + emergency medicine	18 127/36 239 (50.0)	2.1 (2.0–2.2)
Pediatrics	4510/14 251 (31.6)	1.0 (1.0–1.1)
Family medicine	14 097/34 289 (41.1)	1.5 (1.4–1.6)
Other†	1887/3036 (62.2)	3.5 (3.3–3.9)

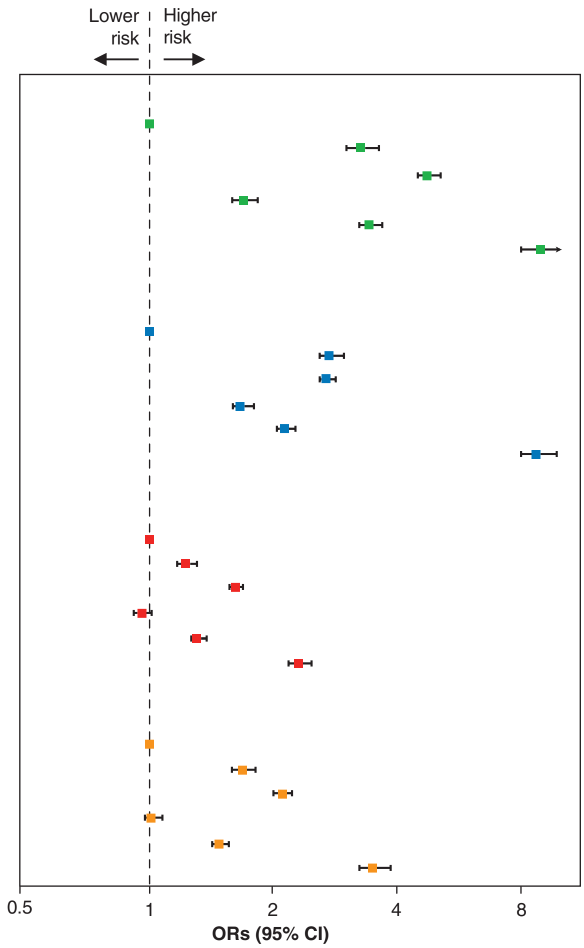

Figure 4: Pediatric radiograph use by physician specialty at Ontario emergency departments between 2010 and 2019. *We performed analyses using a complete case analysis with the following observation counts (*n* [%]) excluded owing to missing data: bronchiolitis (1955 observations [3.2%]), asthma (4971 observations [3.5%]), abdominal pain (7774 observations [2.3%]), constipation (3368 observations [3.0%]). †All models were adjusted for patient age, sex, income quintile, immigrant or refugee status, complex chronic conditions, Canadian Triage Acuity Scale score, time of presentation, physician sex, physician years in practice and physician training background (domestic v. international). Note: CI = confidence interval, DI = diagnostic imaging, OR = odds ratio, ref. = reference.

attention may be paid to keeping up to date with pediatric recommendations. These may result in knowledge gaps with regard to best pediatric practices, partly explaining the increased use of radiographs at these institutions.[45,46,48,59]

Radiograph use was highest in hospitals with higher pediatric volumes. This finding differs from the large body of "volume–outcome" literature suggesting that higher volumes lead to better adherence to guidelines and better outcomes, for both pediatric and adult patients.[38,39,60–63] The discordance might have been driven by the fact that most children in our sample presented to community hospitals. As a result, our high-volume tertile was composed mainly of community hospitals, predominantly oriented toward adult care, with only a minority of patients in that tertile seen in Ontario's 4 pediatric academic hospitals. Another possible explanation is that high volumes in our cohort may have been a surrogate for overcrowding, which leads to increased resource utilization and decreased effective care.[64–67] These explanations limit our ability to interpret the impact of pediatric volume on radiograph use, but suggest that hospital type, rather than pediatric volume, drove the differences in our study.

Improved quality of care has been reported for children treated by pediatric specialists for primary, neonatal, surgical and oncological care.[60,62,68] In the ED setting, findings have been more mixed; PEM physicians were more likely to order low-value tests for patients presenting with lower acuity in 1 study,[42] but less likely to do so for febrile infants in other studies.[33,41] We found fewer radiographs ordered by PEM physicians, suggesting that differences in training may affect radiograph use. This variation could be a result of cognitive biases caused by higher-acuity presentations, higher incidence of chronic disease and higher admission rates in adult EM.[69,70] These suggest that adult patients who visit the ED are sicker and more likely to have

Table 2: Outcomes after pediatric emergency department discharges for Ontario hospitals between 2010 and 2019*

Balancing measure	No. (%)† of patients with bronchiolitis			No. (%)† of patients with asthma		
	Imaging *n* = 22 798	No imaging *n* = 38 116	Risk difference (95% CI)	Imaging *n* = 38 149	No imaging *n* = 103 772	Risk difference (95% CI)
Return ED visits within 7 d	2958 (13.0)	5744 (15.1)	–0.02 (–0.03 to –0.02)	2739 (7.2)	7556 (7.3)	–0.001 (–0.004 to 0.002)
Hospital admission within 7 d	1098 (4.8)	1928 (5.1)	–0.003 (–0.006 to 0.001)	626 (1.6)	1108 (1.1)	0.006 (0.004 to 0.007)
ICU admission within 7 d	57 (0.3)	100 (0.3)	–0.0001 (–0.001 to 0.0007)	33 (0.1)	86 (0.1)	0.00004 (–0.0003 to 0.0003)
	No. (%)† of patients with abdominal pain			No. (%)† of patients with constipation		
Return ED visits within 7 d	10 896 (17.8)	45 689 (16.8)	0.01 (0.007 to 0.01)	4757 (10.4)	5492 (8.5)	0.02 (0.02 to 0.02)
Hospital admission within 7 d	1418 (2.3)	5258 (1.9)	0.004 (0.003 to 0.005)	728 (1.6)	635 (1.0)	0.006 (0.005 to 0.008)
ICU admission within 7	31 (0.1)	95 (0.0)	0.0002 (–0.00003 to 0.00035)	31 (0.1)	26 (0.0)	0.0003 (–0.00001 to 0.0006)

Note: CI = confidence interval, ED = emergency department, ICU = intensive care unit.
*Results for death within 7 days were not reported owing to small cell numbers (*n* = 1–5) in order to ensure data confidentiality. A standardized difference of 0.1 was used as a cut-off to denote substantial imbalances between groups.
†Unless otherwise indicated.

clinically relevant findings on radiographs, which may create a bias among adult EM providers to order more radiographs for children as well. Although general pediatricians consistently ordered fewer radiographs than adult specialists and generalists did, they still ordered more chest radiographs than PEM physicians, suggesting that pediatric exposure in training does not explain all the practice variation reported. The addition of specific skills or exposure to ED-specific clinical practice guidelines in PEM training may also explain some of the variation.[45,46,48]

No studies have specifically evaluated the underlying causes of these differences in low-value radiograph use. Our findings suggest that ED setting and physician specialty training warrant further exploration, perhaps through qualitative studies, to inform future interventions.

Limitations

First, our database did not include data on resource availability at different hospitals. Resource availability is an important driver of practice variation[27,28] and is more likely to affect advanced imaging (e.g., ultrasound, computed tomography or magnetic resonance imaging) than radiographs in the ED setting. This may have affected decision-making in our study: providers working in centres without access to abdominal ultrasound, for example, may be more likely to order abdominal radiographs. However, our findings were robust to sensitivity analyses excluding low-volume hospitals, where such resource constraints are more likely.

Second, our exposure definition for physician specialty may have measurement bias. Multiple physicians of different specialties could have been involved in the care of a child in a single visit. In our database, it was not possible to differentiate which physician was the initial provider for a given encounter. Given that most investigations are ordered on initial contact, radiograph use may have been attributed to a physician who was not involved in the decision-making process. However, our hierarchical approach attributing radiographs preferentially to PEM-trained physicians would have biased our results toward the null hypothesis.

Third, when evaluating return visits as a balancing measure, our data did not include information on the reason for return visit, thus preventing us from knowing whether the return visit was for the same problem or a new problem. However, similar rates of hospital admission and the rarity of ICU admission and death in our sample suggest that this was unlikely to have affected our results.

Fourth, data on the family situation, which may affect decision-making regarding radiograph use, were not available in our health care database. However, our model included proxies for socioeconomic status, such as income neighbourhood quintile and immigration status, accounting for at least some differences in the family situation.

Fifth, our data did not take into account the increased availability of outpatient clinics in larger urban areas. However, we believe outpatient clinics may act as an informal triage system in Ontario, sending only the sicker children to the ED and reassuring the others. For large city centres, this would mean fewer "healthy" kids in pediatric hospitals, again biasing our results toward the null hypothesis.

Sixth, while the cut-off age of 18 years in our pediatric definition is used in most pediatric health services research and the organization of pediatric services in Ontario, it may not reflect the reality that age cut-offs may differ elsewhere.

Finally, the retrospective nature of our analyses forced us to use discharge diagnoses as a proxy for radiograph indication, which does not reflect the natural decision-making process when ordering radiographs. Indeed, clinical practice and guidelines base this decision on symptoms and signs, rather than diagnosis, and we were unable to replicate this in our design.

Conclusion

Over the decade-long study period, low-value radiograph use was frequent for children with 4 common conditions seen in Ontario EDs. Substantial practice variation exists and is driven predominantly by hospital type and physician specialties. Quality improvement initiatives aimed at reducing unnecessary radiographs in children should focus on EM physicians practising in EDs primarily treating adult patients.

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Data sharing: The data sets from this study are held securely in coded form at ICES. Data-sharing agreements prohibit ICES from making the data sets publicly available, but access may be granted to those who meet prespecified criteria for confidential access, available at https://www.ices.on.ca/DAS. The full data set creation plan and underlying analytic code are available from the authors upon request, understanding that the programs may rely upon coding templates or macros that are unique to ICES.

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