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

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REVIEWER 1: Jennifer Payne/ Dalhousie University, Diagnostic Radiology, Halifax, NS

This section consists of two background paragraphs followed by a paragraph describing the study objectives. My general comment, as described below, that I would expect the points raised in each of the first two paragraphs to move from macro to micro (para #1 (imaging generally, then focus on peds; para #2 focus on provider/institution variation in ped care generally then move to ER) as the pediatric population and ER-based care are the foundational concepts for the research questions.

Changes have been made to the introduction. Specifically, the first and second paragraph have been re-organized as suggested in comments 41 and 42 below.

The first paragraph focuses on inappropriate use of imaging as a low value service, however, I found that the prose moves back and forth between pediatric and general populations. For example, the final sentence combines the American Pediatric Choosing Wisely recommendations with the Canadian Choosing Wisely recommendations although the Canadian radiology recommendations are often reserved for adults – I found this a bit misleading in that some might interpret what is being highlighted in the CA guidelines as being pediatric-oriented.

The first paragraph of the introduction has been re-worded as suggested to go from general to pediatric population.

**"*'Low-value care' describes medical interventions without additional benefit when compared to a less costly alternative. Decreasing 'low-value care' has been identified as a priority to reduce wait times, patient exposure to harm and anxiety, and unnecessary costs. Diagnostic imaging (DI) is a major contributor to low-value care in the emergency department (ED), and accounts for 6 of 10 Choosing Wisely recommendations for emergency physicians in Canada. Low-value DI is a particularly important issue for pediatric patients, who are at increased risk of harm because of their increased susceptibility to ionizing radiation, and the harms related to unnecessary treatments associated with DI use.As such, low-value DI use also accounts for 3 of the first 5 American Academy of Pediatrics Choosing Wisely recommendations. While radiographs have not specifically been included in Choosing Wisely recommendations, multiple clinical practice guidelines recommend against their routine use for bronchiolitis, asthma, abdominal pain, and constipation.*
Together, these diagnoses represent 15-20% of all pediatric ED visits."**

42. The second paragraph focuses on the importance of setting and provider type in providing quality care to the pediatric population. Again, I found the prose skips back and forth between ER-relevant and non-ER points, e.g., the reference to primary care and respiratory disease should come earlier in the paragraph before focusing in on ER care. **The second paragraph has been modified to only focus on emergency care in order to avoid confusion between primary and emergency care:**

**"*Practice variation that cannot be explained by patient illness or preferences is labelled as unwarranted, and leads to variations in low-value care. Unwarranted practice variation exists in the emergency care of children, and differences in ED settings are important contributors to this phenomenon. Specifically, EDs with pediatric designation provide higher-value care and are associated with improved outcomes for respiratory emergencies in children.*
Institutions with higher pediatric patient volumes are associated with better adherence to resuscitation guidelines in the ED setting. 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 to other physician
specialties. While some of the aforementioned studies focused on radiograph use in the ED, few studies have looked across multiple diagnoses and/or ED settings to identify predictors of practice variation. 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, to decrease unnecessary radiographs."**

43. The third paragraph outlines the research objectives justifying the choice of conditions as those for which radiograph use is not recommended. Yet the choosing wisely recommendations referred to earlier are not framed in the context of final diagnosis and there is no specific reference provided for this statement. The choice of these conditions needs more justification.

References have been added in the introduction to support the choice of conditions for the study.

44. I'm not sure why the term 'x-ray' is introduced as 'radiograph' has been used throughout this section. Given the focus on x- ray/radiographs, it would have been interesting to know which of these conditions under study are the subject of any of the choosing wisely recommendations – again, the specifics were lacking and the argument about the harms of imaging due to radiation dose does not apply to all imaging modalities (i.e., ultrasound, MRI).

See response A to comment #43 regarding the linking between conditions and Choosing Wisely recommendations.

The focus on x-ray/radiograph has been incorporated earlier on in the introduction, which hopefully ties in the harms related to radiation better: "*'Low-value care' describes medical interventions without additional benefit when compared to a less costly alternative. Decreasing 'low-value care' has been identified as a priority to reduce wait times, patient exposure to harm and anxiety, and unnecessary costs. Diagnostic imaging (DI) is a major contributor to low-value care in the emergency department (ED), and accounts for 6 of 10 Choosing Wisely recommendations for emergency physicians in Canada. Low-value DI is a particularly important issue for pediatric patients, who are at increased risk of harm because of their increased susceptibility to ionizing radiation, and the harms related to unnecessary treatments associated with DI use. As such, low-value DI use also accounts for 3 of the first 5 American Academy of Pediatrics Choosing Wisely recommendations. While radiographs have not specifically been included in Choosing Wisely recommendations, multiple clinical practice guidelines recommend against their routine use for bronchiolitis, asthma, abdominal pain, and constipation. Together, these diagnoses represent 15-20% of all pediatric ED visits.*"

45. There was a lengthy list of data sources provided but it wasn't always clear which data sources mapped to which variables/concepts.

Supplemental table 4 has been added to clarify this.

46. One concern I have pertains to the definition of pediatric as 0-18yrs. The 'cutoff age' for pediatric care differs across institutions, as I understand it, and certainly across the country (ie is a 17-yr old required to attend an adult ER vs a pediatric ER in some jurisdictions). A more conservative definition of pediatric (ie max 16yrs) may have avoided this bias.

We agree. While in Ontario, pediatric ERs will see patients up to 18 years of age, this age cut-off may differ in other jurisdictions. This represents a limitation that has been noted in the manuscript. Please, see the response to comment #9 for additional reasons why this cut-off was chosen and specific changes made in the manuscript.

47. I also wonder if there may be referral biases not accounted for in the analysis. Kids in large city centres with a pediatric hospital may be more inclined to visit that pediatric ER, especially if there any underlying health concerns/conditions, or if they regular visit outpatient clinics – this may not be adequately measured using admin data.

The reviewer raises two important points. Regarding pediatric hospitals seeing children with underlying conditions, we accounted for that by incorporating chronic complex conditions as a variable in the model. In addition, we ran a sensitivity analysis removing children with chronic complex conditions which did not change our findings (see supplemental table 1). Lastly, even though our chronic complex condition variable may not have captured all children with underlying condition, we believe that children with underlying health issues would be more likely to receive radiographs than their healthier counterparts, which would likely have biased our results towards pediatric centres ordering more radiographs than other hospitals, and towards the null hypothesis. Therefore, we believe our results are still valid despite this important potential limitation.

Regarding the regular use of outpatient clinics, evaluating the use of radiographs in the outpatient setting was beyond the scope of this manuscript. In addition, we believe that outpatient clinics would act as an informal triage system in Ontario, sending only the sicker children to the emergency department and reassuring the others. For large city centres, this would mean fewer 'healthy' kids in pediatric hospitals, again biasing our results towards the null hypothesis. This was included in the limitations section of the manuscript using the following language: *"Fourth, 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 emergency department and reassuring the others. For large city centres, this would mean fewer 'healthy' children in pediatric hospitals, again biasing our results towards the null hypothesis."*

48. As mentioned earlier, the analysis is grounded in a defined set of diagnoses on discharge. Given the nature of the data, there is not really another approach, but the limitation of this approach, together with the guidelines for imaging being focused on signs/symptoms (rather than diagnosis after the fact) should be discussed.

**The reviewer brings up an important limitation of the retrospective nature of the study. This was acknowledged in the limitation section of the manuscript using the following language: "*Lastly, 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."**

49. Socioeconomic variables were collected and analysed but there was no discussion/rationale for these variables provided in the introduction.

The association between socioeconomic variables like race, gender, and socio-economic status and the use of low-value radiograph use is well described in the literature. We included the variables that we had access to (income, gender, immigration status) in the model, to adjust for this potential interaction.
A brief justification for this decision, and references to the existing literature, were added to the methods section of the manuscript, using the following language: "*For each index ED visit, we collected patient demographics (age, sex, income quintile, rurality, immigration or refugee status, presence of a chronic complex condition) and characteristics of the ED visit, including Canadian Triage Acuity Score [CTAS], (a validated triage score used to predict illness severity for pediatric patients), time, and day of presentation. We collected characteristics of the physician (sex, domestic vs foreign training, years in practice, specialty), and hospital characteristics (academic status, pediatric patient volumes). These variables were collected to account for their known and possible impact on resource utilization.*"
We chose not to add this in the introduction to respect the word and paragraph limitations.

50. Is a number of 2 pediatric consultations/wk in an ER an appropriate measure of regular access to services? I don't know – no rationale/reference/personal communication was provided for this choice.

In Ontario, we know that access to pediatricians is variable, and that some centres have no access to pediatric consultations, and others have only intermittent access to pediatricians. We felt that this would be an important variable to incorporate in our hospital-type definition, given its potential impact on radiograph use in the emergency department, and the potential interventions we would design to bridge this gap.
As there is no recognized standard for measuring regular access to pediatric services, we used team consensus to define this variable. First, we looked at the distribution of the annual number of pediatric consultations in every centre included in our database. We noticed there was an important drop off in annual pediatric consultations below 100 (corresponding to approximately 2 consultations / week), and after careful consideration, there was consensus in the team that this would be the most appropriate cut-off for access to pediatric services in Ontario.
This was clarified in the methods section of the manuscript using the following language: *"This cut-off was chosen by team consensus, as there are no recognized standards for measuring access to pediatric services at non-pediatric hospitals."*

51. First paragraph – the variables 'rurality and 'immigrant/refugee' were not mentioned in the measures section of the methods

The variables have been added to the methods section of the manuscript.

52. Second paragraph 'the overall use of … was high'
– judgment statements don't belong in results, there is no reference here to say that the number is high (higher than what?) – just report result. Judgment can come in discussion section when referencing literature. Ditto for final paragraph in this section – 'high and stable' – just 'stable'.

The statement was modified to remove any judgment on the trends in the results section.

53. Conceptually, I kept wanting to see the respiratory diagnoses results discussed together, and similarly the abdominal ones – presuming that the symptoms present more similarly which is what the guidelines are meant to address. **We kept the discussions separate for all 4 conditions for multiple reasons:**

First, bronchiolitis and asthma have completely different patient populations. Bronchiolitis is an exclusively pediatric diagnosis, while asthma is also common in adults. As such, we felt it was important to keep the two conditions separate.

In addition, the results were consistent across all 4 conditions. We therefore felt that there would be little value in contrasting respiratory and abdominal conditions, to keep the emphasis on the differences between hospital type, physician specialty and pediatric volumes.

54. Balancing Measures – again, if I take at face values that these are low value imaging tests, then you don't need to prove that by looking at these secondary outcomes (presuming these are what demonstrate value) – again, I don't see how this analysis fits with, or supports, the primary objective.

We felt that balancing measures were important to the analysis for several reasons.

First, we felt the need to account for potential misdiagnoses, as this was at the root of our population selection. If a child is sent home without an x-ray with a diagnosis of asthma, but is admitted a few days later with a diagnosis of pneumonia, then it's possible that x-ray would have been high-value. Our balancing measures give us a stronger argument to convince our audience that these x-rays were truly low-value, since the children who did not receive them had similar rates of adverse events.

55. First sentence – round use was 'high' but no reference to explain relative to what.

The language was modified to 'common' instead of high, at the recommendation of the CMAJ statistician.

56. Sure – I can buy that there may be more focus on quality initiative aimed at adult care, but the intro section of this paper muddies the water between adult and pediatric care, e.g., how many of the Choosing Wisely recommendations deal with pediatric care – maybe there are too few? Not enough attention paid?

The reviewer brings up an interesting point. The introduction has been modified to clarify the distinction between adult and pediatric Choosing Wisely recommendations.

Language in the interpretation section has been re-phrased to: *"Continuing medical education and QI initiatives in EDs predominantly serving adult populations are likely focused on adult issues, and less attention may be paid to keeping up to date with pediatric recommendations"* to incorporate the concept of 'less attention being paid' to pediatric guidelines.

57. As mentioned above, this analysis focused on diagnosis whereas guidelines focus on signs/symptoms – the limitation of the diagnosis- based analysis should be discussed.

As previously discussed in answer to comment #48 – this was added to the limitation section of the manuscript.

REVIEWER 2: Candice Crocker/ Dalhousie University Faculty of Medicine, Department of Psychiatry, Halifax, NS

58. I appreciated the choices of which conditions to examine for inappropriate use of radiographs. However, the exclusion of patients who were admitted to the hospital does not make complete sense to me. The purpose of diagnostic imaging is to determine the severity of what may be happening inside the patient. How do you distinguish a legitimate concern that there is something severe going on that could warrant an admission (and the radiograph) versus a lower risk population based on this exclusion criteria? Was the imaging rate higher in the admitted children as compared to the non- admitted? Using a subanalysis by CTAS score would make more sense from a clinical utility angle if you are aiming for a "lower risk" population. According to table 1, for asthma as an example, the % of the sample that had a CTAS score of 1 or 2 was 33.1%, the use of radiographs in the entire cohort was 27% or not exceeding the % of the cohort for the highest concern patients. In this light, the rate of imaging, especially as it is examined from small community centres to larger academic pediatric ones, does not imply excessive use. What happens if you do this? Are clinicians of all stripes not imaging the less urgent triage categories? This would be laudable and still a point to publish and emphasize.

Please see response to comment #7. Including admitted patients in our cohort would have made it even more difficult to discern whether the radiographs were low-value or not. The rate of imaging in admitted patients would definitely be higher than in discharged patients and, while we can argue the proportion of 'high- value' radiographs in that population is also higher, we still would not have been able to distinguish which were truly indicated. Our decision to exclude admitted patients reduces the risk of including patients for whom a radiograph may have been indicated.

Regarding the analyses excluding patients with a CTAS 1 or 2, CTAS score was incorporated as a covariate in our model. Our results are therefore already adjusted for CTAS score.

59. Why is there no statistical analysis of the trends of radiograph use for each of these conditions over time? A reduction of 43.3% to 35% over the study period for bronchiolitis imaging would seem like a significant decrease. This analysis should be conducted.

We have run a statistical analysis of the trends in radiograph use over time. However, because the number of records is so high, any small difference would be 'statistically significant' but not necessarily 'clinically significant'. We agree with the reviewer that an 8% reduction is a good first step but the current rate of 35% still needs major improvement. We have therefore left the results as previously reported to avoid misleading the readers into thinking the trends are clinically relevant.

A detailed discussion of trends over time was not the aim of this manuscript and has been previously described in the literature (including another paper by this group – see reference #28).

60. On line 18 of page 7 of the submission, you state your dataset had low radiograph use in children with low pediatric ED volumes. This could imply appropriate use or at least a lack of excessive use depending on the usage level (10% of a low number of patients versus 10% of a high number of patients for instance). However, in your discussion of this finding (page 5, line 45) you state that it is surprising that you have a correlation between pediatric volume and pediatric radiograph rates and go on to try and punch as many holes as possible in your data. So is it possible that you have a similar baseline across sites? Odds ratios are key to analyzing this type of data but you have results that suggest some other types of analyses may be needed to fully understand the data.

We agree with the reviewer that lower rates of radiograph use at low-volume hospital suggests a lack of excessive use. This contrasted with the existing literature that had reported better adherence to guidelines in high volume hospitals which is why we were surprised. Because our findings contrast with the existing literature, we explored why this might be the case and were cautious not to make any strong statements about this in our interpretation/conclusions stating that 'these explanations limit our ability to interpret the impact of volume on low-value radiograph use'. A detailed analysis of the interaction between the volume and hospital-type variables was beyond the scope of this manuscript.

The editorialized comment has been removed at the recommendation of the editors.

61. Another point that you do not mention here is the possible influence of access to pediatric ultrasound for the abdominal conditions in particular. Ultrasonography requires skilled staff to both perform and interpret US scans. Do your large community hospitals lack full time US access and that is why radiograph use is stuck at this level? You really focus on training and mention resource allocation in your limitations section but this work could really provide evidence towards under-resourcing this area and the low value radiographs could be just a symptom of "this is all that is available". Can you see in OHIP which hospitals bill US scans as a surrogate for institution access? Or could you use the postal code conversion file to see if these are rural community hospitals with high volume- high radiograph proportions?

Unfortunately, access to ultrasound was not a variable we had access to and therefore could not evaluate this in our analyses. We addressed this in our limitations section.

In addition, lack of access to ultrasound does not justify the use of radiographs for the abdominal conditions chosen. In fact, there is evidence that radiographs use can lead to misdiagnoses and harm for constipation (Freedman et al. J Pediatr 2014 Jan;164(1):83-88.e2 doi: 10.1016/j.jpeds.2013.08.074). As such, although a lack of ultrasound is probably associated with increased radiograph use, it was beyond the scope of this paper to evaluate this association. Lack of resources in community hospitals, and its impact on low-value care, warrants a separate and dedicated evaluation, as the pathways to intervention will be quite different.

62. First paragraph of the background refers to overuse of imaging in the ED, however, the wording of the paragraph makes it sound like the only imaging is radiographs and clearly this is not accurate.

The first paragraph has been modified to remain focused on diagnostic imaging in general, instead of radiographs: *"'Low-value care' describes medical interventions without additional benefit when compared to a less costly alternative. Decreasing 'low-value care' has been identified as a priority to reduce wait times, patient exposure to harm and anxiety, and unnecessary costs. Diagnostic imaging (DI) is a major contributor to low-value care in the emergency department (ED), and accounts for 6 of 10 Choosing Wisely recommendations for emergency physicians in Canada. (10). Low-value DI 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 DI use. As such, low-value DI use also accounts for 3 of the first 5 American Academy of Pediatrics Choosing Wisely recommendations. While radiographs have not specifically been included in Choosing Wisely recommendations, multiple clinical practice guidelines recommend against their routine use for bronchiolitis, asthma, abdominal pain, and constipation."*

63. Also, the in the Canadian EM choosing wisely guidelines only two are for radiographs, the others are for various CT approaches and none refer to ultrasound. Lumping these together and implying it is all referring to radiographs is disingenuous.

See response to comment #62.

64. You state in the abstract that the problem physician group is only EM physicians for the treatment of asthma in academic adult ED. The other three conditions are primarily Family Physician with EM training as the major ordering group. So why then do you conclude that you need to aim QI at adult EM physicians. Would it not have more impact to aim at family medicine with EM?

By adult EM physicians we meant to include both academic EM and general EM physicians (I.e. without pediatric- specific training).

We have re-worded the sentence in the abstract and the conclusion to the following: "*EM physicians practicing in EDs primarily treating adult patients*"

REVIEWER 3: Bijon Das/Dalhousie University Faculty of Medicine, Department of Emergency Medicine, Halifax, NS

65. One EM training pathway could be further delineated - the Family Physician with EM training. These physicians could have been residency trained in EM for one year after their family medicine residency at an academic institution in Canada, OR they could have started EM practice directly out of their family medicine training (at a community or peripheral ED) and challenged the EM exam after two years of practice. This information may be difficult to obtain but could be relevant to the results.

After taking a second look at our physician specialty database (ICES physician database – IPDB), we were unable to distinguish the two training pathways. Number of years in practice was incorporated and accounted for as a variable in the model which should somewhat cover the differences between the two pathways.

This information would also be impossible to integrate in the data at this point, as it would require contacting all the family + EM physicians in our database individually and asking their training pathway, as the distinction is not available in the CPSO database.

Lastly, we do not think that the slight difference in training pathways would significantly affect the results of this study but plan to explore the underlying causes of practice variation between physician specialties in subsequent studies.