# An Analysis of Canon Intelligent Noise Reduction Processing Applied to Pediatric Digital Radiographs

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## Introduction

The focus of this white paper is to discuss the ionizing radiation of digital radiographs, radiation dosing as it pertains to pediatric populations, and how artificial intelligence like Canon Intelligent Noise Reduction (Canon INR) deep learning neural network (DLNN) can address these topics to assist both the patient and the physician. We directly evaluated the application of the Canon INR DLNN software in clinical practice and observed how the implementation of AI technology can impact pediatric digital radiography dosing protocols.

## Radiation

Ionizing radiation is the basis for production of diagnostic radiographs. However, it has long been proven to increase the risk of cancer.[1] Digital projection radiography is an imaging modality of particular importance due to it accounting for a majority of medical imaging. Alongside being the most commonly used diagnostic imaging, it adds up to approximately 23% of the annual collective patient ionizing radiation exposure.[2] Reduction of ionizing radiation and maintenance of diagnostic image quality is a balancing act between these two factors healthcare providers undertake to ensure the improvement of one does not come at the detriment of the other. The ideal of minimal exposure with maximal image quality is hampered by obstructive image graininess referred to as noise. The noise content is inversely correlated to radiation dose, creating a need to balance image quality and patient exposure to ionizing radiation.[3] Image processing is of particular importance for pediatric populations who are known to be especially radiosensitive.[4,5] We evaluated the capabilities of Canon Intelligent Noise Reduction (Canon INR) DLNN software in relation to standard and decreased dose pediatric digital radiographs.

## Artificial Intelligence:

Deep learning neural network (DLNN) artificial intelligence (AI) software integration in radiology has shown notable applications in both image quality improvement and radiation dose reduction protocols.[6] DLNN, through exposure to digital radiography images, can build hierarchical algorithms to identify and remove image noise better than current rules-based noise-reduction algorithms.[7] This examination of Canon INR expands upon a gap in present digital radiography AI literature. The majority of AI research is currently focused on imaging modalities such as computerized tomography.[3,7,8]

## Analysis of Quality Improvement by Canon INR

A Duke 07-646 Phantom was used to evaluate image quality and noise content prior to applying the Canon INR to patient clinical images. The resulting positive impact on image quality during this testing by the physicist affirmed the decision to proceed to clinical evaluation with real patients.

A total of 1251 digital radiographs (abdomen, extremities, spine, chest and head/shoulder/pelvis/hip) were gathered from 649 pediatric patients at Dayton Children's Hospital South Campus. All patients' images seen by pediatric radiologists at this location were included, no patients were excluded. Preliminary image collection was performed for 2 weeks, during which, the Canon INR software was programmed and calibrated using radiographs at standard dose. A total of 559 radiographs from 229 patients were collected at standard dose over a 6-week period. The radiation dosages were subsequently reduced by 20-25% for an additional 4 weeks, during which 212 images from 145 patients were evaluated. Additional collection with a final 40-50% dose reduction continued for 8 weeks, yielding 480 radiographs from 277 patients. Six pediatric radiologists evaluated images post-Canon INR on a scale of "worse", "same", or "better". Preliminary one sample chi-squared tests for each region of the body and each phase of dose reduction were performed to analyze qualitative effectiveness of Canon INR. A Kruskal-Wallis one way analysis of variance (ANOVA) was performed to evaluate exposure index (EI) values in order to explore the significance of dose reduction throughout the study.

A separate survey was given to the same 6 radiologists to evaluate each individual's perception about the technology. The survey questions asked if any loss of detail was perceived, if the noise reduction was considered effective, if images were clinically diagnostic, if lower dose images with INR were comparable to standard dose without, and if radiologists found the software worthwhile based on the as low as reasonably achievable (ALARA) principle.


*Figure 1: Comparison of a lateral lumbar spine radiograph before (left) and after(right) CANON INR software using standard dosing protocol (pre-existing exposure factors)*

*Figure 2: Comparison of a anteroposterior (Grashey) shoulder radiograph before (left) and after (right) CANON INR application using low dose reduction protocol (20-25% lower exposure factors)*


*Figure 3: Comparison of an anteroposterior abdominal radiograph before (left) and after (right) CANON INR application using low low dose reduction protocol (40-50% lower exposure factors)*

**Results:**

Of the 1251 images, 995 were rated “better”, 250 rated “same”, and 6 were rated “worse” compared to pre-Canon INR processing counterparts. All radiographs generated, including after a 50% reduction in radiation dose, yielded images sufficient for diagnosis. Overall, a one sample chi-squared test of radiologist feedback was statistically significant $X^2(2, N=1251)=1273.127$, $p<0.0001$, refuting the null hypothesis the software had no impact on image quality. Similarly, analysis of ratings for each phase of dose reduction and grouped anatomic areas showed a statistically significant difference (Table 1).

*Table 1: Chi-squared analysis of specific protocols*

| Protocol | $X^2$ value | df | N | p-value |
|---|---|---|---|---|
| Standard dose | | | | |
| *Abdomen* | 169 | 2 | 96 | p<0.0001 |
| *Extremities* | 120.801 | 2 | 272 | p<0.0001 |
| *Spine* | 64.836 | 2 | 55 | p<0.0001 |
| *Chest* | 183.982 | 2 | 109 | p<0.0001 |
| *Head/Shoulder/Pelvis* | 26 | 2 | 27 | p<0.0001 |
| 25% dose reduction | | | | |
| *Abdomen* | 92 | 2 | 46 | p<0.0001 |
| *Extremities* | 113.818 | 2 | 88 | p<0.0001 |
| *Spine* | 34 | 2 | 17 | p<0.0001 |
| *Chest* | 78.533 | 2 | 45 | p<0.0001 |
| *Head/Shoulder/Pelvis* | 11.375 | 2 | 16 | p=0.0034 |
| Final dose reduction | | | | |
| *Abdomen* | 156.621 | 2 | 87 | p<0.0001 |
| *Extremities* | 222.136 | 2 | 236 | p<0.0001 |
| *Spine* | 66.408 | 2 | 49 | p<0.0001 |
| *Chest* | 83.143 | 2 | 84 | p<0.0001 |
| *Head/Shoulder/Pelvis* | 37 | 2 | 24 | p<0.0001 |

*p<0.05 is statistically significant

Kruskal-Wallis one way ANOVA of exposure index (EI) found there was a statistically significant difference in exposure index values between the EI protocols. After refuting the null-hypothesis, pairwise comparisons between each dosage protocol were formed to determine which relationships contained a statistically significant change. Each group comparison was found to have a statistically significant reduction in exposure index with a $p<0.0001$.

Examination of the radiologist feedback survey found all the radiologists agreed the noise reduction capabilities of the software were effective and INR processed images were clinically diagnostic. Five radiologists reported no loss of detail, with one reporting occasional loss. When asked if the INR processed images were clinically diagnostic, every radiologist answered yes. The radiologists were in unanimous agreement regarding lower dose INR processed images were at baseline comparable to standard dose images without INR.

**Conclusions:**

The results of the qualitative assessment of Canon INR's abilities effect on image quality by radiologists reinforces current literature surrounding DLNN and its abilities to positively impact radiology. Our data suggests Canon INR is effective and assists radiologists in diagnostic imaging. The analysis of clinicians' ratings for radiograph comparison before and after Canon INR application showed a significant difference showing most radiographs deemed "better '' following INR application. The EI results reflect that changes to dose protocol yielded a significant decrease in radiation exposure. Further investigation could lead to changes in standard dosage guidelines, thereby possibly lowering ionizing radiation exposure to patients, particularly of the pediatric population.[7] The exposure index prompting an evaluation of the hospital's exposure protocols was a secondary positive effect on patient dose exposure. Through changes in protocol throughout this study with the use of INR technology, the dose used for obtaining radiographs sufficient for diagnosis was reduced by a total of 50% across all anatomical regions, showing progress in movements to reduce pediatric exposure of carcinogenic radiation. The overwhelming distribution of "better" rated digital radiographs alongside the ability to lower patient dosing by 50% has exciting implications moving forward. Pediatric patients can be exposed to less harmful ionizing radiation without disrupting the physicians' ability to diagnose and the improved diagnostic image quality observed in this study reinforces Canon INR's capabilities to improve workflow.

**Future Considerations:**

While showing promising results, constraints arose due to the preliminary nature of the Canon INR diagnostic efficacy assessment. The installation of the Canon INR was limited to the Dayton Children's South Campus, therefore the sample size of clinicians available to evaluate image quality was restricted to 6 radiologists. The subjective nature of the image ratings is another factor to be considered; radiologists' preferences varied ratings for diagnostic improvement. Distribution of data collected amongst providers is skewed, with one radiologist rating 64% of the radiographs. Further subjective evaluation is thus needed for a better representation of this novel technology. Because of patient safety, this study only compared before/after using the same radiograph taken at a decreased dose. The comparability to standard dose has yet to be determined. While clinicians overall did not perceive a loss in detail or deemed radiographs with application of Canon INR to maintain minimum requirement for diagnosis, a more comprehensive statistical analysis evaluating qualitative factors, such as signal-to-noise ratio of every image collected, is warranted for future quantitative evaluations.

## References


1. **Yasser F. Ali, Francis A. Cucinotta, Liu Ning-Ang, Guangming Zhou. Cancer Risk of Low Dose Ionizing Radiation. Frontiers in Physics. 2020;8. doi:10.3389/fphy.2020.00234**
2. ***Volume I REPORT TO THE GENERAL ASSEMBLY SCIENTIFIC ANNEX A: Evaluation of medical exposure to ionizing radiation*. (n.d.).**
3. **Chen H, Zhang Y, Zhang W, et al. Low-dose CT via convolutional neural network. Biomed Opt Express. 2017;8(2):679-694. Published 2017 Jan 9. doi:10.1364/BOE.8.000679**
4. **Zewdu M, Kadir E, Berhane M. Assessment of Pediatrics Radiation Dose from Routine X-Ray Examination at Jimma University Hospital, Southwest Ethiopia. Ethiop J Health Sci. 2017;27(5):481-490. doi:10.4314/ejhs.v27i5.6**
5. **Nemoto M, Chida K. Reducing the Breast Cancer Risk and Radiation Dose of Radiography for Scoliosis in Children: A Phantom Study. Diagnostics (Basel). 2020;10(10):753. Published 2020 Sep 25. doi:10.3390/diagnostics10100753**
6. **Martini K, Barth BK, Nguyen-Kim TD, Baumueller S, Alkadhi H, Frauenfelder T. Evaluation of pulmonary nodules and infection on chest CT with radiation dose equivalent to chest radiography: Prospective intra-individual comparison study to standard dose CT. Eur J Radiol. 2016;85(2):360-365. doi:10.1016/j.ejrad.2015.11.036**
7. **Schmidhuber, J. (2015). Deep Learning in neural networks: An overview. In *Neural Networks* (Vol. 61). https://doi.org/10.1016/j.neunet.2014.09.003**
8. **Brady SL, Trout AT, Somasundaram E, Anton CG, Li Y, Dillman JR. Improving Image Quality and Reducing Radiation Dose for Pediatric CT by Using Deep Learning Reconstruction. Radiology. 2021;298(1):180-188. doi:10.1148/radiol.2020202317**