

Maximizing Dose Efficiency for Pediatric Patient Imaging

Introduction

Radiographic imaging of pediatric patients presents a number of unique challenges compared to the imaging of adults. The increased radiation sensitivity of growing organs and bones, children's longer expected life spans and the large range of body habitus encompassed by this patient demographic all mean that it's not appropriate to use the same acquisition techniques and image-processing parameters used for adult imaging. The Image Gently campaign's "Back to Basics" initiative encourages the use of pediatric-specific imaging practices and is completely consistent with the guiding principles in Carestream's approach to addressing these important issues.^{1 2 3}

To provide the highest quality image with the most efficient use of the radiation exposure, it's important to address each step in the image-formation chain as part of a complete system. The image-formation process can be naturally divided into three distinct stages: image acquisition, image processing for display, and image review and assessment. These steps are represented in Figure 1. The process of image-quality assessment and its essential role in driving positive feedback into the acquisition and image processing steps are also indicated in this figure.

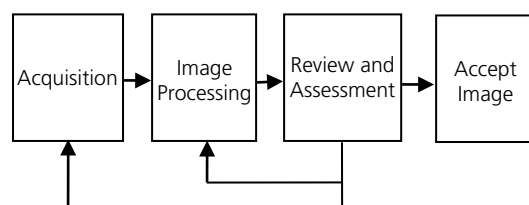


Figure 1. Flow diagram for the image-formation process. Image review and assessment allow for feedback into the acquisition and image-processing steps, which can drive continued improvement.

In keeping with the spirit of the Image Gently initiative, Carestream Health has developed and implemented a number of product features specifically aimed at ensuring optimal image acquisition and display of diagnostic information across the full range of pediatric patients. The following sections outline some of these capabilities.

Image Acquisition

The first stage of image formation is the capture of the X-ray image by the image receptor. The introduction of Carestream's wireless DRX detector products has been a major step forward in the provision of a high-quality X-ray detector that fits seamlessly into the workflow of the NICU and pediatric ICU. In addition, the use of a CsI(Tl) X-ray absorption layer helps to ensure the highest possible image quality. The design virtually eliminates the problems that can be encountered with patient positioning in a busy clinical environment when a tethered system is used. The replaceable battery also guarantees that the detector is ready for use at a moment's notice.

In addition to a highly efficient detector, it's also essential to use the appropriate acquisition protocols (e.g. kVp, mAs and filtration) across the wide range of pediatric body habitus. The wide range of body sizes – from the smallest neonatal patient to the largest adolescent – requires acquisition techniques to be tailored to each patient's size and age. To help with this challenge, Carestream offers the ability to select the pediatric patient body size from a range of seven categories, based on the recent FDA recommendations.^{4 5} This categorized selection allows the system to choose default acquisition parameters and image-processing configurations appropriate for the different types of patients as well as the different detector types (Pediatric Capture

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Image Optimization & Enhancement Software). This capability provides a more consistent acquisition and display of images for patients within a given body size and age range.

Carestream is also engaged in research to develop improved acquisition techniques for pediatric patients. This work is based on the realization that the use of a digital receptor opens the possibility for targeting a specific signal-to-noise ratio in the image, versus maintaining a specific optical density within the final image. The inherent separation of the acquisition and display of an image in the digital environment provides new

opportunities to develop task-specific tailoring for the amount and type of radiation used to create digital images.

To illustrate the opportunity for technique optimization, Figure 2 shows a normalized image-quality metric (detectability index per unit of effective absorbed dose) for a 5-10mm sized lung nodule, as a function of patient weight. The results indicate that for smaller patients, a lower kVp can provide improved image quality for a given patient dose, while higher kVps are more beneficial for larger patients. (The results are normalized to those for the 70kVp technique.)

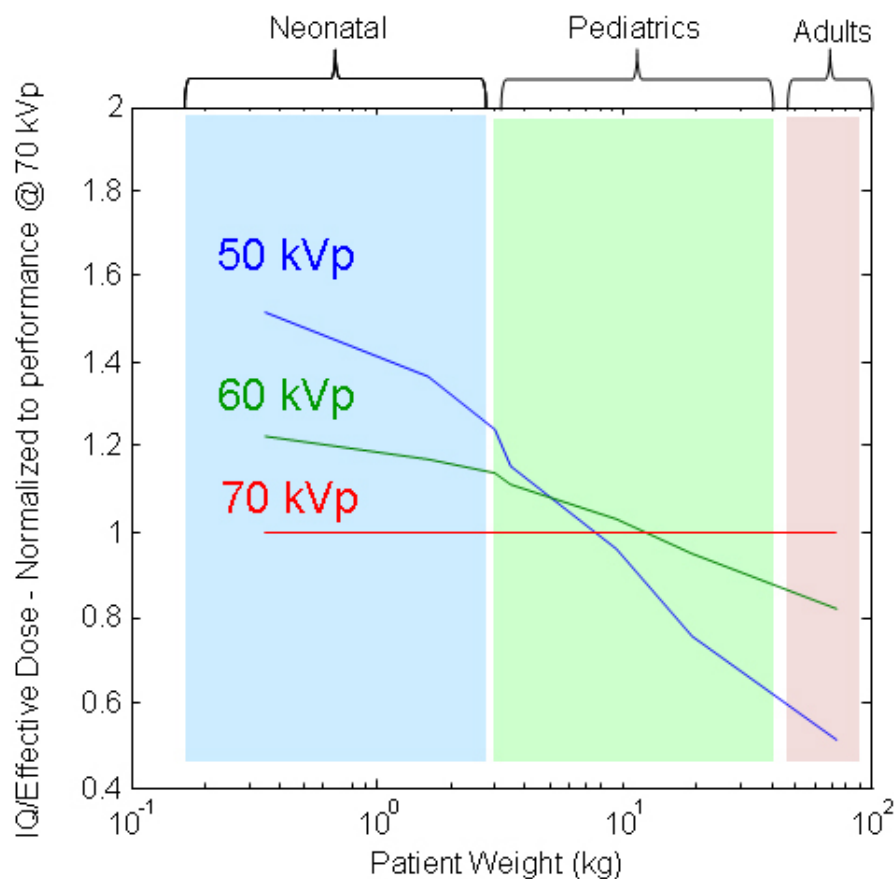


Figure 2. Normalized image quality (nodule detectability index) per unit absorbed effective dose for different kVps as a function of patient weight for a 5-10mm lung nodule. The data is normalized to the image quality result for the 70kVp case.

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In certain procedures, such as scoliosis exams, it may be possible to reduce the exposure levels used for the follow-up images. Exposure reduction works if the imaging task can be satisfactorily achieved with an image that is noisier than the high-quality primary exam but still provides sufficient delineation of the spinal processes to allow accurate clinical evaluation. In this specific example, in addition to investigating dose-reduction strategies, Carestream Health has also implemented a long-length imaging capability that minimizes the amount of overlap between consecutive images. This reduces patient exposure and ensures maximal coverage of the anatomical field of view.

Once an image has been acquired, the rapid display of the preview image allows the radiographer to quickly decide whether the patient's anatomy was correctly captured or if the image needs to be retaken. This improves the speed and efficiency involved in completing exams, which is particularly important for young patients. To help, Carestream has implemented the new IEC Exposure Index (EI) standard for quick assessment of the amount of radiation used to create the image.⁶ The associated Deviation Index (DI) allows an immediate evaluation of the acquisition technique compared to the institutional target of exposure for the given exam. This immediate feedback, coupled with the other developments in technique selection described above, helps the radiographer

provide more consistent image quality from the detector to the next step in the imaging chain, the image processing.

Image Processing and Display

Once a high-quality image has been acquired at the lowest possible patient exposure, it's essential to perform appropriate image processing that presents the diagnostic information clearly and most efficiently to the radiologist. Carestream's EVP Plus Software can be tailored to adjust the image-processing parameters to an individual site's preference. With information about the patient's size and age, the IP parameters can also be adapted to display the features of the clinical information in a more informative way compared to using adult image-processing configurations. The eight-band frequency decomposition, multi-frequency noise reduction and controlled edge-restoration capabilities mean that the available clinical content of the bony structures in the smallest NICU patients can be appreciated as well as the trabecular detail of older more developed patients, as one example. The fine detail and lower contrast of the smallest NICU patient's anatomy requires accentuation of different frequency components than the features of the larger adolescents. Figures 3 and 4 illustrate these differences and show the improved visualization provided by careful selection of the appropriate image-processing parameters.

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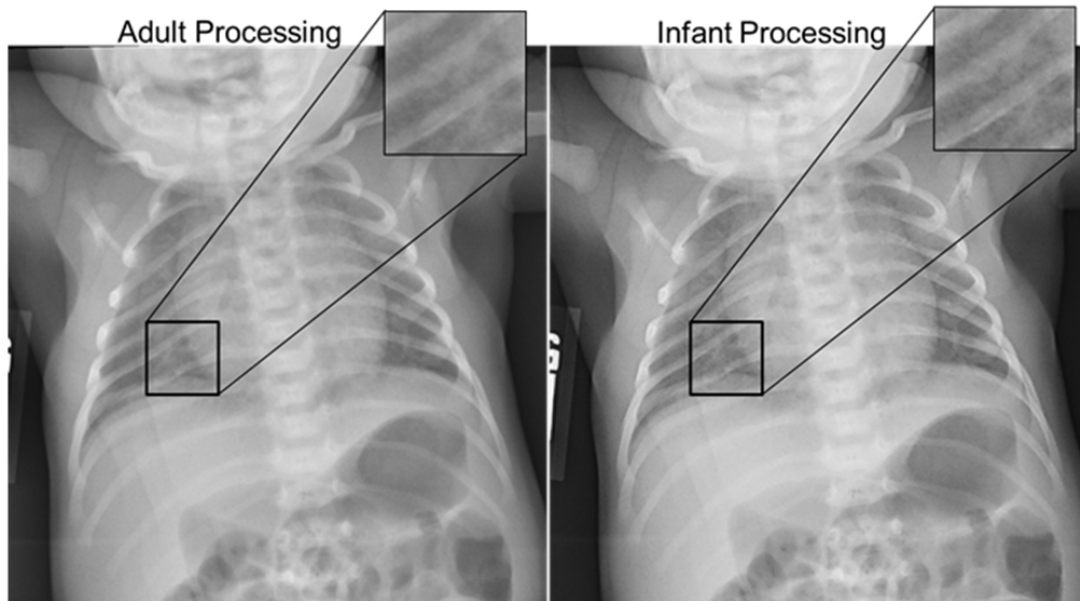


Figure 3. An infant chest image processed with both adult (left) and infant (right) image processing. Note that many infant chest details are not apparent when using adult processing.

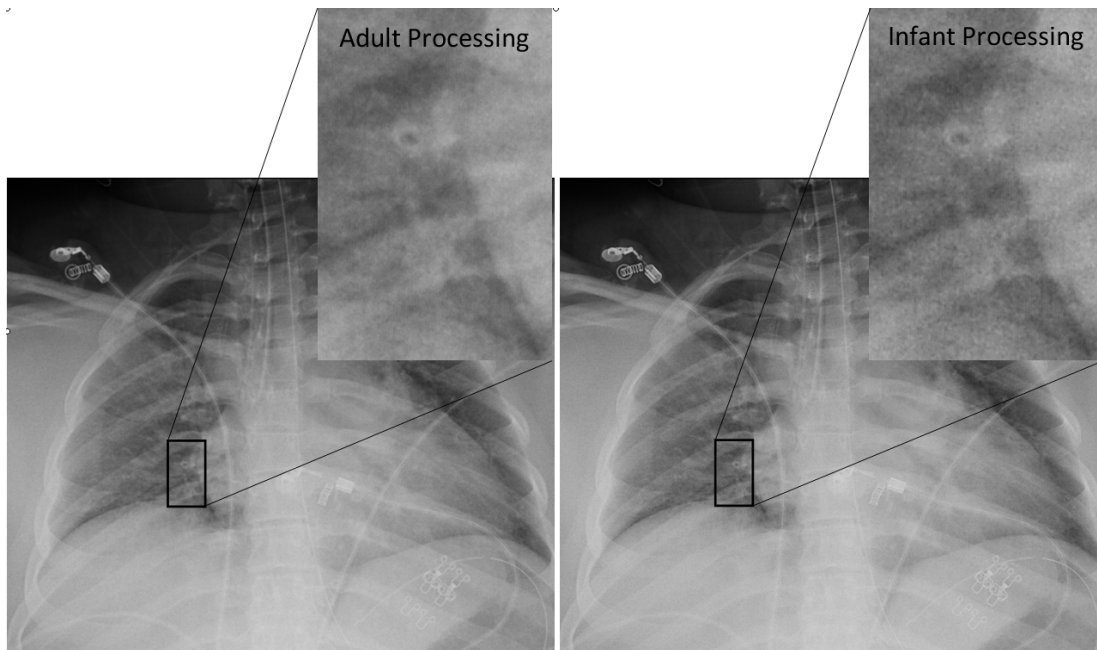


Figure 4. A teenage chest image processed with both adult (left) and infant (right) image processing. Note that fine details of the teen chest are overemphasized when using infant processing.

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Quality Acceptance and Control

Once an imaging system has been installed and tailored to a site's preferences for patient exposure and image "look," it's important to have an ongoing quality control (QC) program in place that ensures the continued high quality of the images delivered to the reading radiologist. There are multiple aspects to this type of QC program and Carestream Health has implemented a number of system capabilities that enable a site to easily track many of the important parameters.

At the front end, the DR Total Quality Tool (DR TQT) package allows for efficient evaluation of the digital X-ray detector's current performance level. In addition, the IEC EI allows quick evaluation of the exposure levels used to acquire the images. On a departmental level, the Administrative Reporting and Analysis Software allows the

QC technician or physicist to query all the Carestream systems across the institutional network from a single, central location. This can quickly highlight anomalous exposure levels, high repeat rates or other image-quality issues that can develop, and allows for more proactive steps to solve potential problems. Together, these system capabilities can help technologists maintain their high level of image quality and consistency.

Conclusion

The unique demands of pediatric imaging require a system-wide approach to guarantee high-quality imaging at the lowest possible patient exposure. Carestream Health offers a range of features and functionality that ensure our systems can provide the best and safest possible X-ray imaging across the full clinical range of exams for all pediatric patients.

¹ Bulas DI, et al. AJR Am J Roentgenol. 2009 May;192(5):1176-8. Image Gently: Why We Should Talk to Parents about CT in Children.

² AJR Am J Roentgenol. 2009 May;192(5):1169-75. Image Gently Vendor Summit: Working Together for Better Estimates of Pediatric Radiation Dose from CT. Strauss KJ, et al

³ Image Gently®: The Alliance for Radiation Safety in Pediatric Imaging. <http://www.pedrad.org/associations/5364/ig/> (Accessed September 27th 2012)

⁴ FDA guidance entitled "Pre-market Assessment of Pediatric Medical Devices," May 14, 2004, <http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM089742.pdf>

⁵ FDA draft guidance entitled "Draft Guidance for Industry and Food and Drug Administration Staff: Pediatric Information for X-ray Imaging Device Pre-market Notifications," May 10, 2012, <http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM302938.pdf>

⁶ International Standard IEC 62494-1 (2008) Medical electrical equipment—exposure index of digital X-ray imaging systems—Part 1: definitions and requirements for general radiography. International Electrotechnical Commission, ISBN 2-8318-9944-3

⁷ Seibert J.A., Morin R.L., "The standardized exposure index for digital radiography; an opportunity for optimization of radiation dose to the pediatric population", Pediatric. Radiol. 41(5), (2011), 573-581