Radiation dose reduction in Digital Radiography – no compromise in image quality

By Sangwoo Lee, Ph.D.

Thanks to its improved usability and superior image quality, Digital radiography (DR) has been rapidly replacing existing projection radiography techniques. In current state-of-the-art DR systems, the X-ray dose in most routine chest exams is considered to be negligible compared to the radiation dose involved in CT. However, despite this advantage, it is still important to rigorously apply the ALARA principle to daily clinical exams particularly when a patient (especially a pediatric patient) has to undergo repeated exams over a long period of time or when significantly higher X-ray doses are required to examine body areas such as the abdomen [1-5]. For example, neonatal patients in Neonatal Intensive Care Units (NICUs) and pediatric patients with scoliosis typically have to undergo numerous DR exams throughout the course of their treatment.
The accumulated X-ray dose can be significantly high.

In this article, we describe the dose reduction methods used in the Samsung GC85A and GM85 DR systems. The GC85A model, with its new imaging engine S-Vue 3.02 has recently been cleared by the U.S. FDA for use at 50% dose reduction for adult chest exams. In addition, Samsung's SimGrid™ and Bone Suppression software open up new possibilities for further reduction in X-ray dose by eliminating unnecessary radiation exposures with a workflow improvement.

50% DOSE REDUCTION WITH S-VUE 3.02 FOR CHEST EXAMS

The new S-Vue 3.02 imaging engine uses a multi-scale image processing system to preserve detailed imaging features while suppressing unwanted image noise. Figure 1 shows the conceptual workflow of the system . The imaging engine first estimates the noise from the raw image in order to implement advanced noise reduction using multi-scale filtering, and then adds noise whitening to produce the final DR image.
In a study based on phantoms and presented at RSNA 2017 [6], it was found that the current version of the imaging engine yielded improved results in key image quality parameters such as Signal-to-Noise-Ratio (SNR) and Contrast-to-Noise-Ratio (CNR), as compared to the previous version of the imaging system [6].
In this study, anatomic and physical image quality scores of the DR images of the anthropomorphic chest phantom were evaluated. It was found that the total image quality scores of S-Vue 3.02 were higher than those of the previous version of the system at all dose levels. In fact the total image quality score of S-Vue 3.02 at 75% dose reduction was similar to that

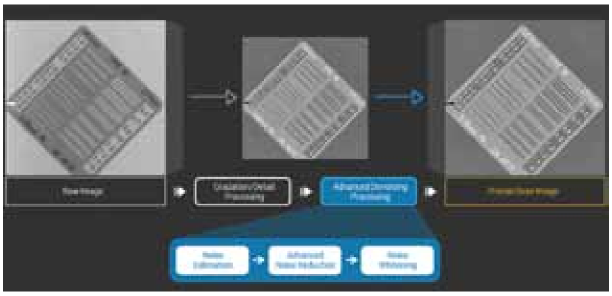

Figure 1. Schematic view of the S-Vue 3.02 workflow. Noise is reduced and image details maintained.

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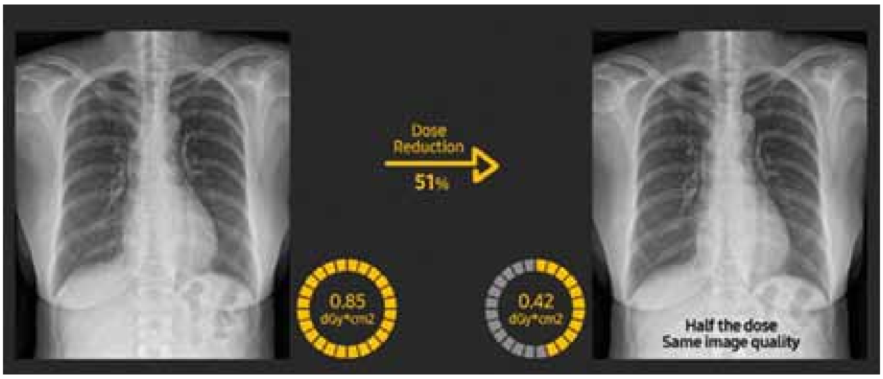

Figure 2. Chest PA comparison images Left: 120kVp, 0.76Gy-cm2, BMI 23.7, 14.17μSv, Right: 120kVp, 0.37Gy-cm2, BMI 23.7, 6.73μSv), Courtesy of Dr. Semin Chong, Chung-Ang University Hospital, Korea

of the previous engine at 100% full dose.
In order to validate the clinical performance of the imaging engine, a clinical trial involving 70 patients was carried out [7]. Key anatomic features such as radiolucency of the lung, pulmonary vascularity, trachea, edge of rib, heart border, intervertebral disc space, and pulmonary vessels in retrocardiac area were evaluated using a five point Likert scale. The new S-Vue3.02 was found to be non-inferior to the previous version in all anatomic features at 50% reduced dose. Figure 2 shows the comparison of a typical clinical PA chest image with one obtained in the same patient using the S-Vue3.02 at a level of 51% dose reduction.

THE USE OF SIMGRID™ FOR WORKFLOW ENHANCEMENT AND DOSE REDUCTION

An anti-scatter grid (also known as a grid or physical grid) is the most widely used technique to reduce X-ray scatter in radiography. Such scatter reduces tissue contrast, and degrades the diagnostic quality of DR images. While the use of a grid is common in fixed DR systems, it is often omitted in mobile DR systems because the proper alignment of source and grid/detector is not always favorable. Even for fixed DR systems, there are a few limiting factors for using grid.

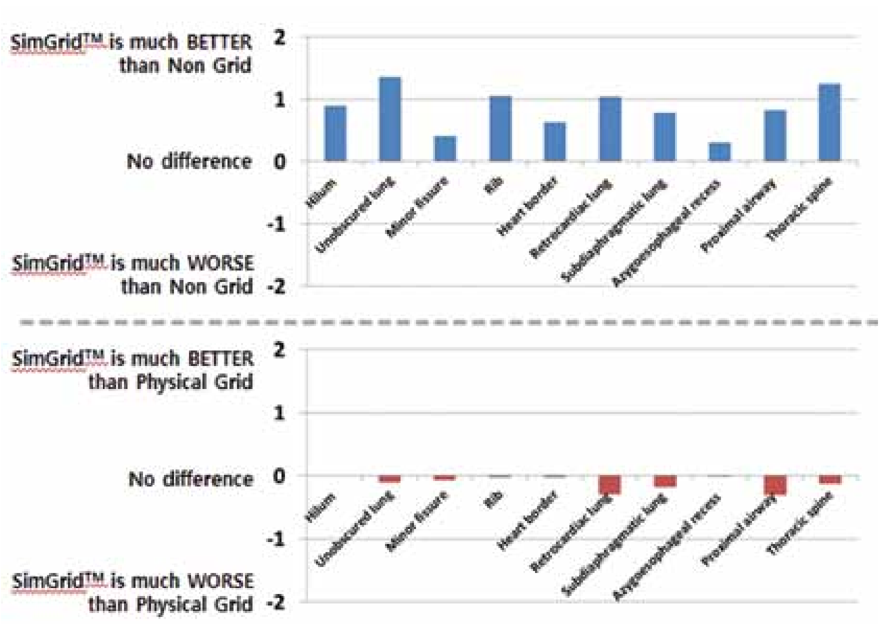

Figure 3. Comparisons of SimGrid vs non grid (Top) and SimGrid vs physical grid (Bottom)

The grid frequency, or the number of grid septa per centimeter, needs to be sufficiently high, so that the width of grid bars is significantly smaller than the detector element size. Otherwise, the grid bars will be visible on DR images, creating so called grid artifacts. Since modern detector elements are getting much smaller for higher spatial resolution, the manufacturing of grids with higher frequency is becoming more challenging and costly. The use of a grid also means that fewer X-ray photons will arrive at the detector element because of the absorption by grid septa and interspace material. Therefore additional radiation is often required in examinations using a grid compared to non-grid exams.

SimGrid™ is a new post-processing software provided with Samsung DR systems. The software automatically estimates the scatter field from each patient examination, and then subtracts the scatter from the raw image so as to reconstruct images with a reduced scatter effect. The software has been evaluated in an observer-preference clinical trial involving 38 patients [8].
This study showed that SimGrid™ improved the image quality of non-grid images in all 10 anatomical features almost to the level of images acquired with a grid.
The average dose that was obtainable using non-grid exams with SimGrid™ was 18.7% less than that with grid exams. Figure 3 shows the preference score for each comparison. Figure 4 shows typical images from the clinical trial.

USE OF BONE SUPPRESSION WITHOUT EXTRA RADIATION EXPOSURE

Detecting subtle lung lesions within chest X-ray images is often obscured by bone structures. In a National Cancer Institute lung cancer screening study, it was reported that the bone structures obscured 35% of the lung cancers [9]. The dual energy subtraction technique was introduced to overcome this limitation by reducing bone signal. This method uses the second

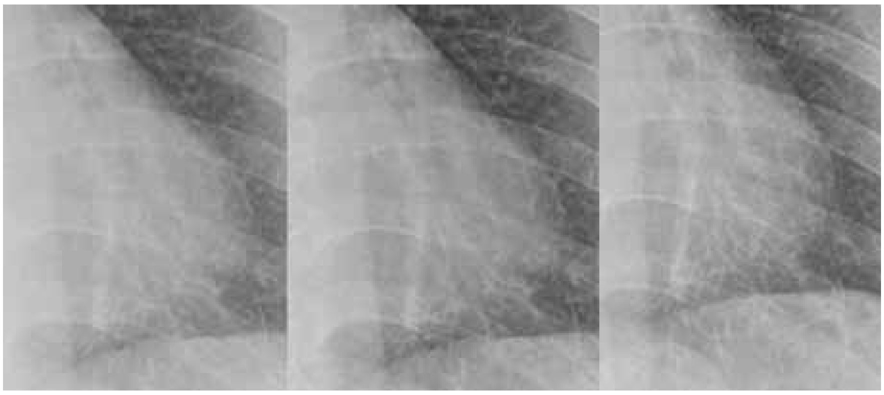

Figure 4. Magnifications of anteroposterior chest radiographs. Improved delineation of the retrocardiac opacities is seen in SimGrid image (middle), as well as grid image (right), compared with non-grid image (left). Courtesy of Dr. Jin Mo Goo, Seoul National University Hospital, Korea

X-ray exposure at a higher kVp and longer exposure time which results in an additional 15% radiation [10].

By using Bone Suppression in a single chest X-ray exam, the extra radiation involved in the dual energy subtraction can be avoided. In addition any motion artifacts are reduced. The Bone Suppression module estimates the bone structure from each patient image based on a pre-trained CNN (Convolutional Neural Network) model.

The system was evaluated in a retrospective study with 160 patients [11]. When Bone Suppression was used to provide an additional image to help readers find a lung lesion, the diagnostic performance increased with a higher area under the curve (AUC) and sensitivity [11]. Figure 5 shows a clinical example from the study where multifocal opacities from pneumonia were easily detected in a Bone Suppression image.

CONCLUSION

All the results and data presented above were acquired in normal, adult-sized patients. It has therefore not been established in direct studies whether the imaging engine and software described here would give the same performance with pediatric or larger patients. Different patient anatomies could also result in a different level of performance.

Nevertheless, despite these reservations, several clinical trials in average-sized adults have shown the promising results that the Samsung DR system can provide. Without any sacrifice in image quality the system enables a significant reduction in the radiation dose used in daily clinical practices. Thus the Samsung DR system can ultimately help radiologists and patients whose common goal is to have a reliable and accurate diagnostic result with a minimum risk of radiation exposure.

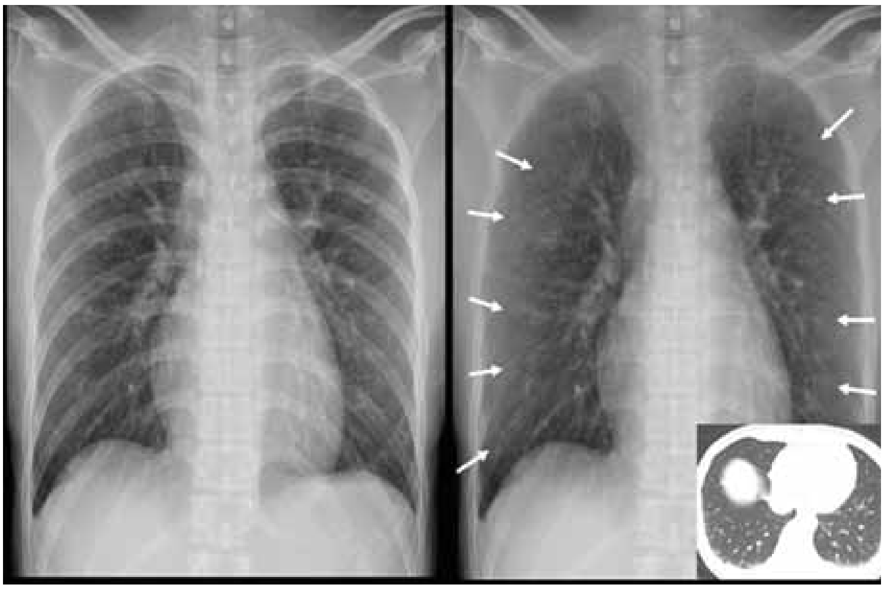

Figure 5. Multifocal patchy increased opacities. Routine chest X-ray (left) and Bone Suppression image with findings. Courtesy of Dr. Gil Sun Hong, Asan Medical Center, Korea

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