Optimizing Radiation Dose for GC85A

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Introduction

Since the site installation of Samsung's X-ray system, Samsung Medical Center (SMC) has exerted efforts to reduce patient radiation dose and acquire optimal images on the principle of ALARA (As Low As Reasonably Achievable). SMC's diagnostic capability has improved with new image post-processing and beam quality optimization techniques in Samsung's premium X-ray GC85A system. In this paper, we show the results of phantom evaluation tests and in vivo dose optimization experiments in routine chest X-ray imaging.

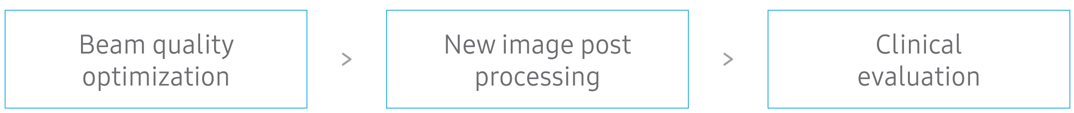

Figure 1. Flow diagram for the dose optimization

Methods

As the first step for the evaluation of Samsung X-ray system's dose optimization capability, the X-ray beam quality was optimized via quantitative/qualitative tests under various kVp, mAs, filtration conditions using a phantom. After the beam quality optimization, the new image post-processing software was applied. The resulting images were examined by radiologists to validate whether the image quality could be maintained throughout the test while scanning dose was gradually reduced.

1. Dose Metric

Diagnostic Reference Level is the referred recommended dose level when patient radiation doses in medical diagnostic tests are measured and evaluated. In 1996, six international organizations including World Health Organization (WHO) and International Atomic Energy Agency (IAEA) established Basic Safety Standards (BSS) N0.155, which sets forth recommended radiation dose levels for ionizing radiation projection on patients [1]. Entrance Skin Dose (ESD), which is recommended in BSS No.155, was used as a measure of dose level. ESD was calculated by either after measuring the Entrance surface exposure (ESE) and considering Backscattering Factor (BSF), or by direct estimation. Experimental BSF value of 1.3, obtained from the separate dose test in SMC, was used.

2. Beam quality optimization

Diagnostic X-rays are emitted in a continuous spectrum from the X-ray tube. This continuous spectrum ranges from low energy components, which cannot pass through the body, to high energy components, which reduce image contrast. The low energy components merely increase the radiation dose since they are absorbed into the patient's body and do not contribute to the formation of diagnostic images. To reduce the level of exposure dose, an additional filter can be placed in front of the X-ray tube, which will remove low energy components [2]. This additional filter is commonly made of copper (Cu) and Aluminum (Al) materials which can adjust the X-ray energy properly.

Aside from the basic filter, Samsung's GC85A system allows automatic addition of copper filters with three different thicknesses (0.1, 0.2, and 0.3 mm). This additional copper filter was utilized in this study to optimize beam quality.

When copper filter was used, the average energy of X-ray was increased and image contrast was reduced. Therefore, X-ray tube voltage had to be adjusted accordingly to solve this issue.

2-2. Noise reduction image processing with edge preserving

Low-dose scanning, which aims to reduce exposure dose in patients, can lead to a noise increase and reduced visibility of necessary information in diagnostic images. Generally, when noise reduction processing is applied to the images, the boundaries of organs can become blurred which, in turn, can make diagnosis difficult despite the reduced noise level.

Samsung's new image post-processing technique can compensate such disadvantage by reducing noise effectively while preserving organ and vessel boundaries. With this processing technique, image quality in terms of SNR (Signal to Noise Ratio) and CNR (Contrast to Noise Ratio) can still be maintained even under low-dose conditions.

3. Phantom study

The effectiveness of beam quality optimization and post-processing technique was tested under low-dose conditions using DIGRAD phantom (Pehamed; Germany). The dose reduction trial was performed under existing conditions in the medium build adult PA protocol. The tube voltage was reduced by 10 kVp, an additional 0.1 mm Cu filter was added, and the ESD values were decreased to as low as 30%. Lastly, new post-processing technique was applied to the scanned data.

Table 1. X-ray exposure conditions for quantitative evaluation

Protocol	ESD [μGy]	kVp	Additional filter	New image processing filter
Reference condition (Chest PA Factory setting)	115.0	120	Not applied	Not applied
119%	136.9			
93%	107.0			
74%	85.1			
59%	67.9	110	0.1 mmCu	Applied
45%	51.8			
37%	42.6			
30%	34.5			

A quantitative image quality evaluation was conducted on the result images from tests under different scanning conditions. Mean SNR and CNR values in high-contrast and low-contrast patches of the DIGRAD phantom were compared with the values acquired under reference condition.

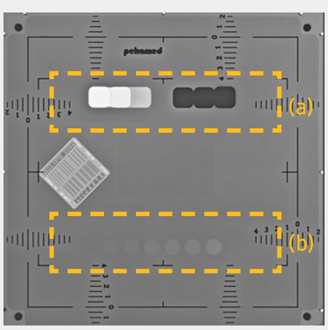

Figure 2. DIGRAD Phantom image - (a) High contrast patch (b) Low contrast patch

4. Clinical image

An in-vivo clinical evaluation was performed from October 2015 to January 2016 at SMC. During the evaluation, a scanning scheme where the dose level was reduced gradually was implemented to acquire patient images. The chest PA and AP protocol images on the follow-up patients were evaluated by two radiologists who compared the images with those of other protocols in use at the time. When the images were evaluated as appropriate for use in diagnosis, the scanning dose was reduced to the next lower level. The reduced dose rates were set to be 80%, 65%, 50%, 40%, 22% of the reference dose, and scanning was conducted three to five times iteratively. Unlike the phantom study, the reference dose was set as SMC standard protocol. When the image quality was determined to have been degraded at a certain dose rate, the iteration step was stopped and the dose rates from the previous scanning condition were determined to be optimal.

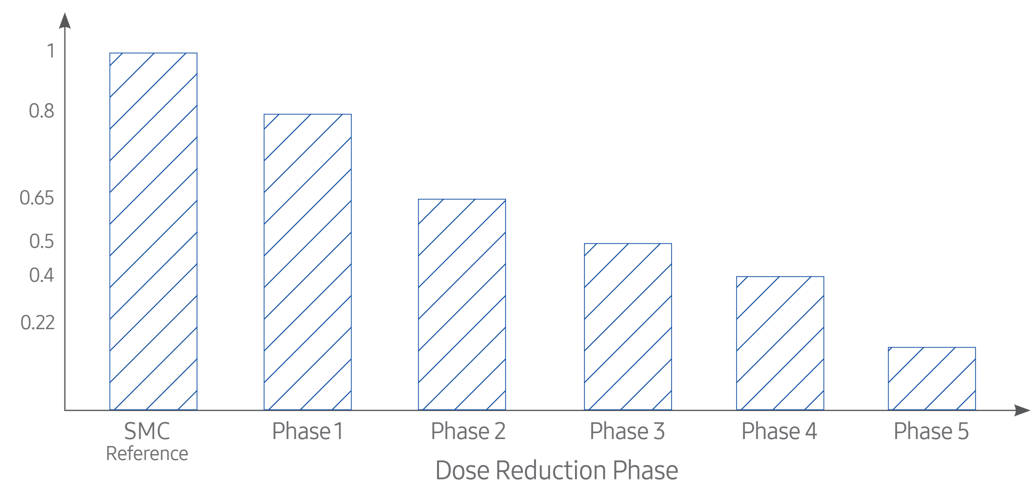

Figure 3. Dose reduction ratio

Results

1. Phantom study

From phantom (DIGRAD) test, the SNR values in the high and low contrast region at 35% and 55% reduced dose levels were similar to the reference values. For CNR, the values at 45% and 60% reduced dose levels were the same as reference values. It can be concluded from the SNR and CNR results that when optimized beam is used and improved post-processing techniques are applied to the result images from reduced-dose scanning, the image quality will match that of the result images from reference condition. Especially, the image quality in low contrast region can be maintained. Considering that low-dose images are vulnerable to noise which deteriorates the detectability of lesions in low contrast region, it can be inferred that optimized beam and improved post-processing techniques can compensate this disadvantage.

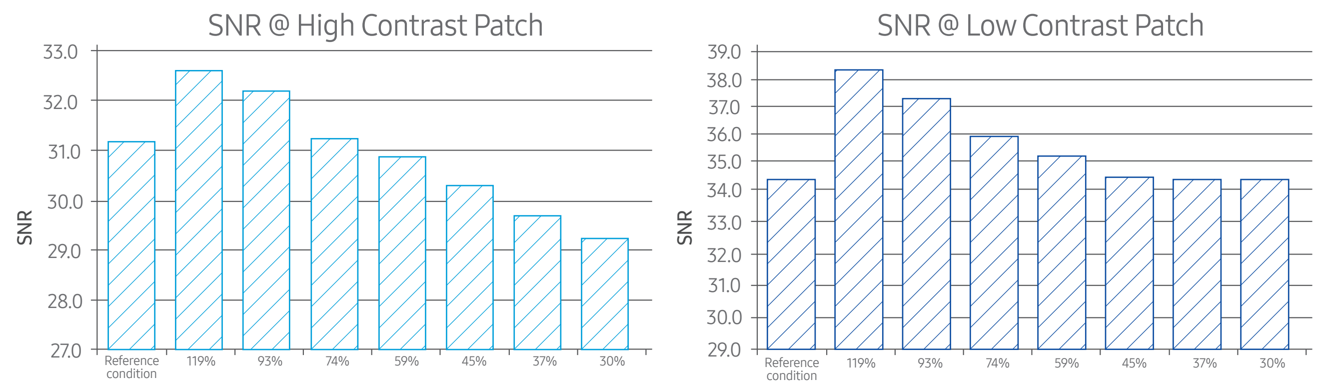

Figure 4. SNR graph at different dose rates

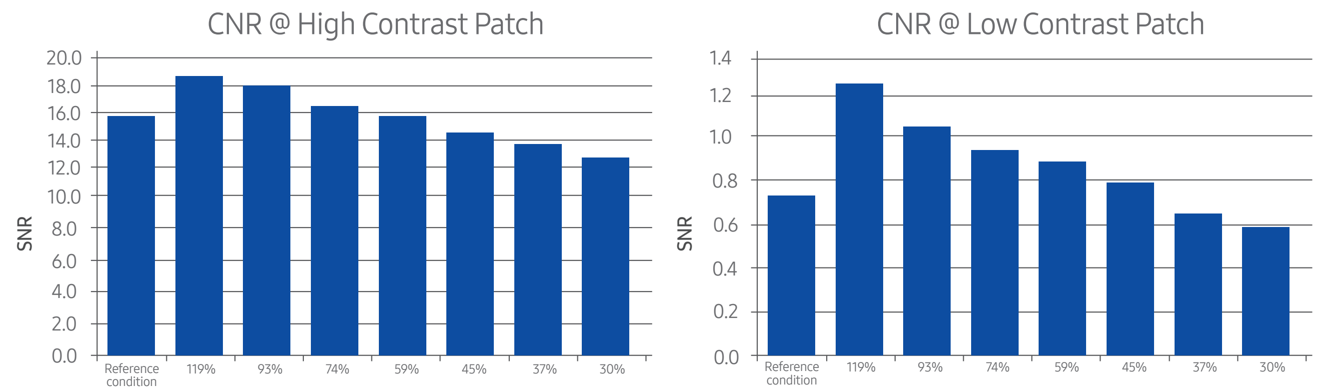

Figure 5. CNR graph at different dose rates

2. Clinical image

The optimized dose rates derived from the tests using patient data in SMC is in the table below. It can be observed that a maximum level of 53.1% and 53.2% in dose reduction can be achieved for adult chest PA and adult chest AP respectively.

Table 6. X-ray exposure conditions for quantitative evaluation

Protocol		ESD [µGy]		Dose reduction ratio [%]
		SMC reference	Optimized	
Chest PA	Small	61.4	40.4	34.2
	Medium	49.5	23.2	53.1
	Large	90.1	55.0	39.0
Chest AP	Small	137.4	64.2	53.2
	Medium	268.7	136.8	49.1
	Large	556.6	266.2	52.2

According to the evaluation of radiologists, the image quality of resultant images from optimized-dose scanning on the same patient was found to be equal or even better than that of the resultant images from reference condition. In addition, it was confirmed that the diagnostic features of optimal dose images were not impacted by new post-processing software.

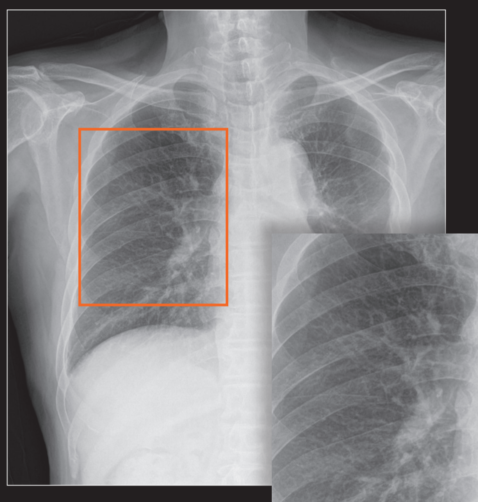

Figure 7. Chest PA at normal dose (Left, 120 kVp 3.05 mm Al filter (inherent@75 kVp), 55.0 µGy) and optimized dose (Right, 110 kVp 3.05 mm Al filter (inherent@75 kVp) + Cu 0.1 mm filter (additional) 33.7 µGy) in the same patient

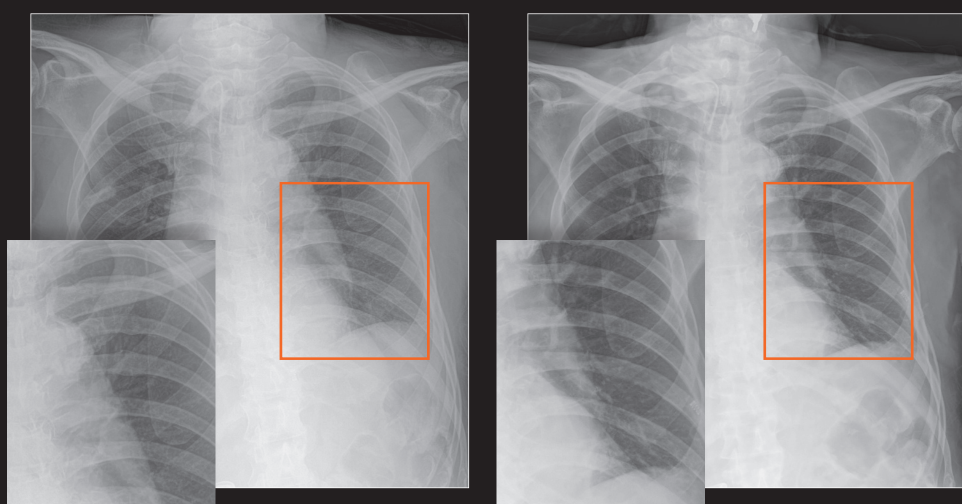

Figure 8. Chest AP at normal dose (Left, 75 kVp, 3.05 mmAl filter (inherent@75 kVp), 270.6 µGy) and optimized dose (Right, 75 kVp 3.05 mm Al filter (inherent@75 kVp) + Cu 0.1mm filter (additional) 138.5 µGy) in the same patient

Conclusion

The clinical evaluation conducted at SMC achieved about 40 to 50% of dose reduction with Samsung's premium X-ray system and improved post-processing technique. The reduced dose rates are 92% of the reference value which are recommended by the American Associate of Physicists in Medicine (AAPM, 2005)[2], and about 93% of values in Ministry of Food and Drug Safety (MFDS, 2003) [3] report on chest PA (the medium build adult) protocol. Compared with the recommended values in other countries, the reduced dose rates are 92% of those in Germany (Federal Office of Radiation Protection; BfS, 2003) [4] and 85% of those in the U.K (Health Protection Agency; HPA, 2006) [5]. The result images did not lose any diagnostic ability with reduced dose rates. This paper concludes that Samsung GC85A system can reduce patient radiation dose for chest protocols and relieve anxiety of the patients without sacrificing image quality.

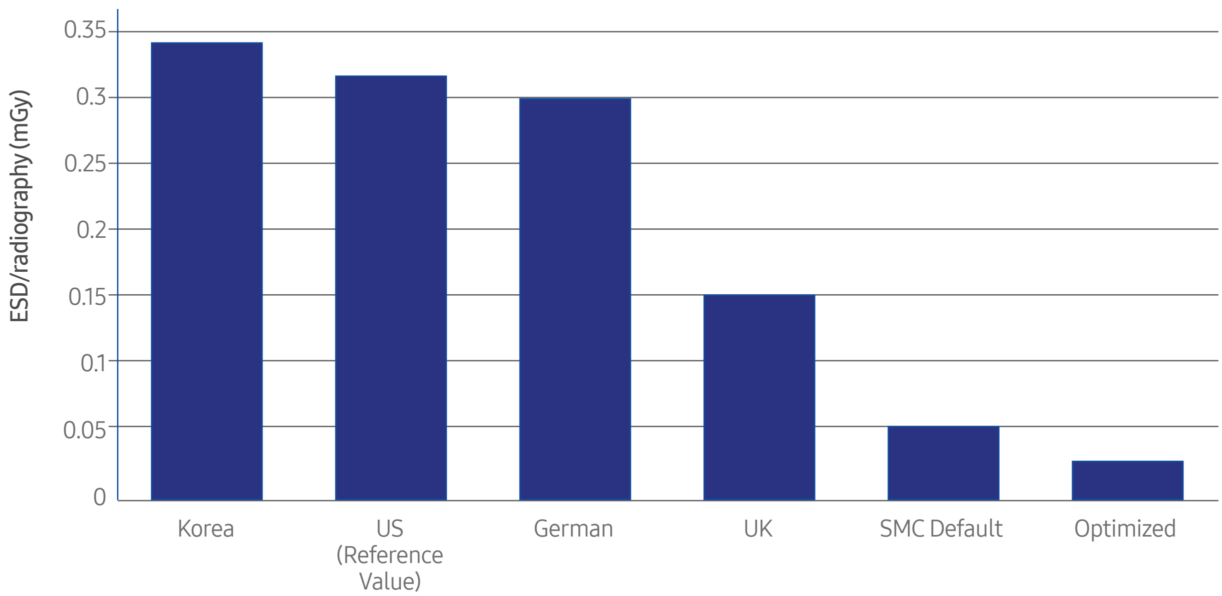

Figure 9. Optimized dose level compared with dose guidelines (Chest PA protocol)

References

[1] International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources Safety Series (BSS) No. 115, IAEA (1996)

[2] Reference values for diagnostic radiology: Application and impact, Gray et al., Radiology (2005); 235:354-358

[3] 일반영상의학검사의 환자선량 권고량 가이드라인 - 두부,흉부,복부,골반,경추,흉추,요추, 식품의약품안전청 (2012)

[4] 방사선검사 및 핵의학검사에 적용되는 진단참고준위 공시-독일연방방사선방어청 (2003)

[5] Doses to Patients from Radiographic and Fluoroscopic X-ray Imaging Procedures in the UK-2010 Review, HPA (2012)

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