Contrast Enhancements and Workflow Improvements Provided by AutoGrid™ Software

White Paper | GE Healthcare's AutoGrid™ Software

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Abstract

GE Healthcare's AutoGrid Software focuses on providing X-ray images acquired without an anti-scatter grid equivalent image quality (IQ) compared to those acquired with the grid. AutoGrid's ability to deliver contrast improvements equivalent to those achieved with a physical grid provides the opportunity for decreased exam times and retakes, resulting in a potential decrease in overall dose delivered to the patient and an increase in patient comfort and department productivity.

Figure 1: Chest phantom comparison of images acquired without a grid, with an anti-scatter grid (8:1 ratio) and without a grid with AutoGrid (Medium strength) processing.

Introduction

Scatter radiation is a hindrance inherent to portable and table-top digital cassette X-ray examinations. Depending on patient size and anatomy of interest, an anti-scatter grid may be recommended to increase contrast detail by reducing the amount of scatter X-rays that reach the detector. Use of an anti-scatter grid during a portable or table-top exam comes with inconvenient workflow practices as well as constrained patient positioning and alignment during acquisition. In addition, a considerable number of images acquired in a clinical setting with a grid are not acquired at a source to image distance (SID) equivalent to the optimal focal distance of the grid.[1] These common obstacles during acquisition may cause nonuniformities and reduced IQ within the image that may lead to retakes and subsequently higher total dose delivered to the patient during the exam.

As a result, clinical sites may decide to reduce the risks by using grids with lower ratios or by eliminating their use altogether for these exams. Both "solutions" produce images with substantially higher amounts of scatter, inducing sub-optimal contrast within the image and potentially masking of subtle signs of disease.

AutoGrid's dynamically adaptive processing eliminates these risks by reducing the scatter to deliver IQ that rivals that of an image acquired with a physical anti-scatter grid. Through the use of anatomical phantoms of varying sizes and exhaustive clinical testing, AutoGrid has been designed to reduce the low frequency scatter adaptively to each individual acquisition at multiple strength levels that are configurable by the user.

The AutoGrid Algorithm

GE Healthcare's AutoGrid is an adaptive low-frequency scatter reduction algorithm that increases contrast in an image acquired without an anti-scatter grid to the level of an image acquired with a grid of up to a 12:1 ratio.

AutoGrid is by default applied to images acquired using a digital cassette protocol where an anti-scatter grid is recommended, but is not physically attached to the detector. **This allows AutoGrid to be effortlessly applied to the necessary protocols simply by omitting the grid from the workflow**. Based on this criterion of grid recommendation, AutoGrid is applied to a large range of anatomies and views in adult patient sizes that greatly benefit from a reduction in scatter.

AutoGrid supports three different strength levels corresponding to three commonly used grid ratios: 6:1, 8:1 and 12:1. With three different levels, AutoGrid provides the capability to customize looks for different anatomies based on radiologists' preferences. A default strength can be selected to be automatically applied at acquisition and the image can be quickly reprocessed with a different strength using the AutoGrid feature in the Quick Toolbar.

Utilizing a configuration of numerous parameters along with a 2D FFT convolution, AutoGrid generates a low-frequency scatter estimate that is removed from the image to boost contrast levels. The AutoGrid configuration parameters are specific to anatomy of interest, patient size, acquired view (antero-posterior, postero-anterior, lateral, etc.) and selected AutoGrid strength, ensuring the best possible IQ for each protocol.

Although the configuration file is structured to fit a specific exam protocol, the scatter estimation is not a "cookie cutter" process. AutoGrid utilizes these sets of parameters in a manner in which the acquired image data drives their effects by taking into consideration acquisition technique and dynamic thickness changes within the image. By using real-time, data-driven kernel generation the produced scatter map is unique from case to case.

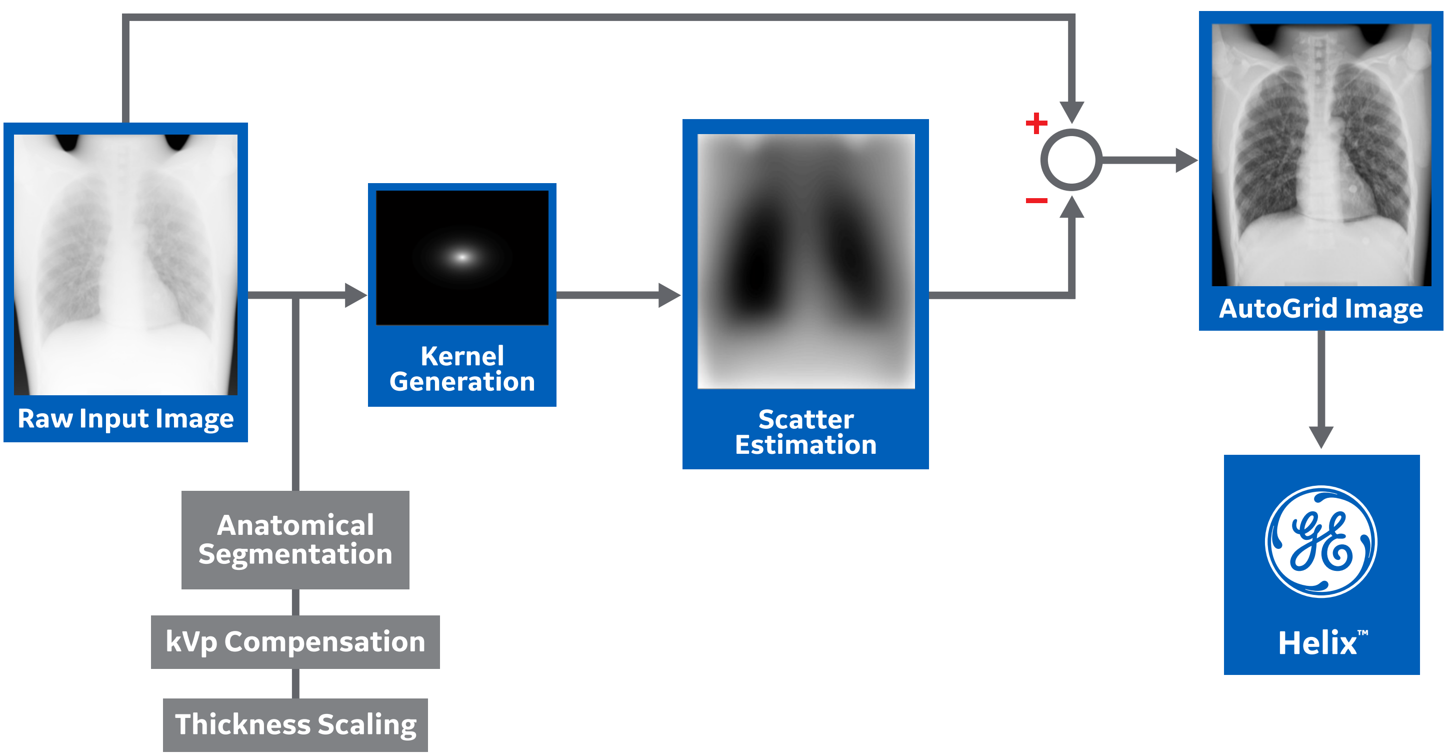
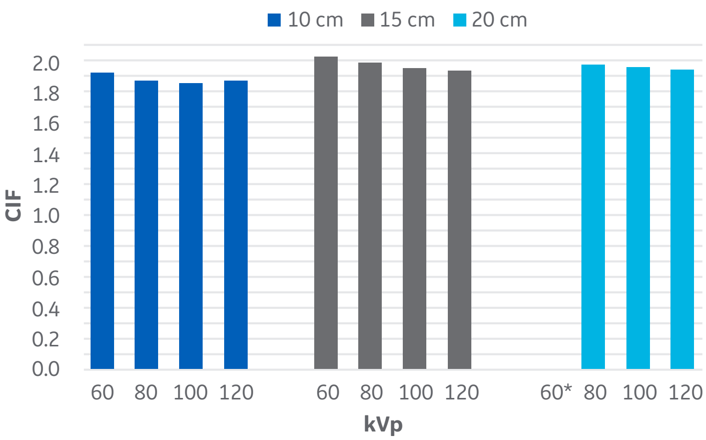


Figure 2: Abridged model of the AutoGrid algorithm.

To ensure consistent performance with different techniques the algorithm includes kVp compensation. This feature allows the user to be able to acquire the same anatomy, view and patient size at numerous technique settings without compromising AutoGrid's performance to remove the scatter. Through the measurement of contrast improvement factor (CIF), Figure 3 demonstrates AutoGrid's ability to provide consistent IQ across varying techniques. The CIF is the ratio of the contrast produced by utilizing a scatter reduction method, such as grid, or in this case AutoGrid, compared to the contrast measured in images acquired without a grid.[2]

The scatter profile is heavily dependent on the thickness and composition (bone, tissue, etc.) of the imaged portion of the anatomy. A subset of the AutoGrid parameters were designed and optimized to segment certain portions of the image that correspond to specific thickness levels. These individual portions of the image are then handled uniquely in the scatter estimate.

By creating a dynamic scatter map, AutoGrid tailors the scatter removal and contrast enhancement to distinct portions of the imaged anatomy ensuring high IQ and smooth transitions for even the most complicated cases.



$$CIF = \frac{CR_{Grid\ or\ AutoGrid}}{CR_0} \quad (1)$$

$$CR_0 = \text{No grid image contrast}$$

Figure 3: Contrast improvement factor (CIF, eq (1)) calculated at multiple techniques using water phantoms of varying thicknesses (10, 15 and 20 cm) with centrally placed aluminum ROIs. *Data at 60kVp with the 20 cm water phantom is not clinically realistic and therefore was not included in this study.

The Anti-Scatter Grid

Three fundamental aspects for the use and proper alignment of a focused anti-scatter grid are: accurate focal distance, perpendicular placement of the grid plane to the central X-ray and grid center line alignment to central X-ray axis.

Focused anti-scatter grids enhance IQ by selectively rejecting scatter radiation through lead strips that are parallel at the center of the grid and are increasingly slanted inward further towards the sides (Figure 4, a). The angle of the lead strips determines the focal distance and subsequent SID needed within the setup. Without the proper alignment, a subset of the primary X-rays are absorbed by the grid's lead strips causing additional primary radiation loss known as grid cutoff (Figure 4, b).

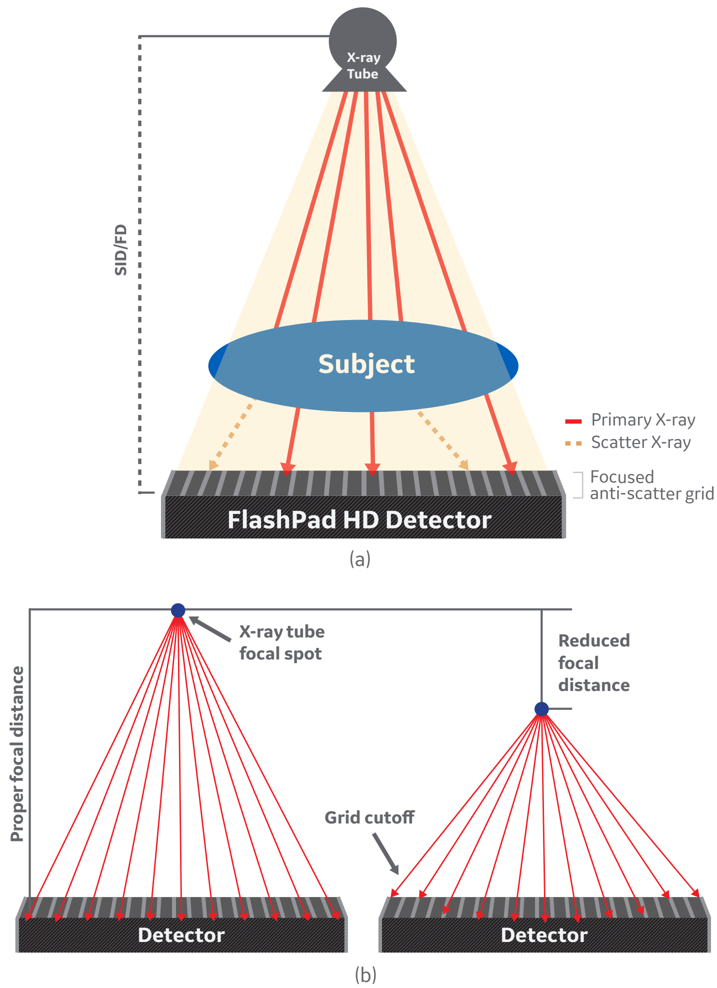


Figure 4: (a) Focused anti-scatter grid and its selective rejection of scatter radiation produced through interactions of the primary beam with the imaged subject. (b) Demonstration of inaccurate focal distance and the absorption of primary X-rays by the grid's lead strips resulting in grid cutoff.

AutoGrid Workflow Improvements

Obtaining the proper SID within a clinical setting especially during bedside exams in the space-limited emergency and ICU rooms can be very difficult. In cases where the patient covers the entire detector surface, it can be almost impossible to accurately measure SID using the traditionally provided measuring tape.

Patient comfort also poses a considerable challenge in the proper placement of the detector. Depending on the patient's condition and general demeanor the simple task of placing the detector behind or underneath the patient can be difficult. Aligning the detector becomes an even more sensitive process when a grid is attached. Now the technologist not only needs to be concerned with the detector capturing the entire region of interest, but they must also consider the angle of the X-ray to the grid plane and the central X-ray beam alignment to the grid's center line located behind the patient.

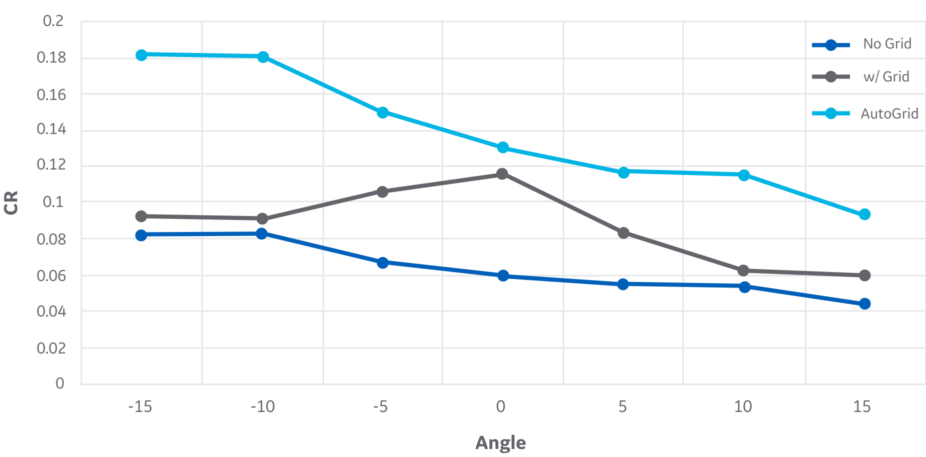
Figure 5 demonstrates the importance of proper detector + grid to tube alignment. The contrast ratio (CR, as defined in eq (2)) measurements were performed using an anatomical chest phantom with a disc, 10 mm in diameter and 5 mm thick, located in the abdomen. Images were acquired in three different manners: with an anti-scatter grid (8:1 ratio), with no grid attached and with no grid attached plus AutoGrid processing at a strength of Medium. As the angle between the tube and the detector strays away from 0˚ alignment, the measured contrast ratio decreases within the abdominal ROI in the images acquired with a grid.

The plot also demonstrates that the angle has a negligible impact on AutoGrid's ability to properly remove scatter and provide consistent contrast level improvements.

After each exam that uses an anti-scatter grid, the grid is detached for cleaning and detector storage and charging. This continuous attaching and detaching of the grid overtime naturally degrades the quality of the grid and it will inevitably need to be replaced. By utilizing AutoGrid, radiology departments can **better preserve the integrity of their grids and avoid the financial burden of replacing them as often**.

As mentioned, AutoGrid is automatically applied to the appropriate exams when a physical grid is not attached, therefore saving time during each exam. An in-house study was performed where a technologist conducted the same exam 30 times utilizing an anatomical phantom and alternating between with grid and AutoGrid exams. The procedures for these exams included steps that are typical to clinical mobile X-ray acquisitions, from starting a patient exam to closing the exam and sending the acquired images to PACS, with the only variations being the act of attaching a physical grid or not.

By removing the grid from the process (attaching, aligning, cleaning, etc.) and utilizing AutoGrid, **the exam times were decreased on average by 35.4 seconds (~24%)**. AutoGrid gives back valuable time to hospitals and clinics that would otherwise be lost with the traditional gridded exam methods, increasing department productivity and decreasing patient wait and procedure times.



$$CR = \frac{I - I_b}{I_b} \quad (2)$$

$*b = background$

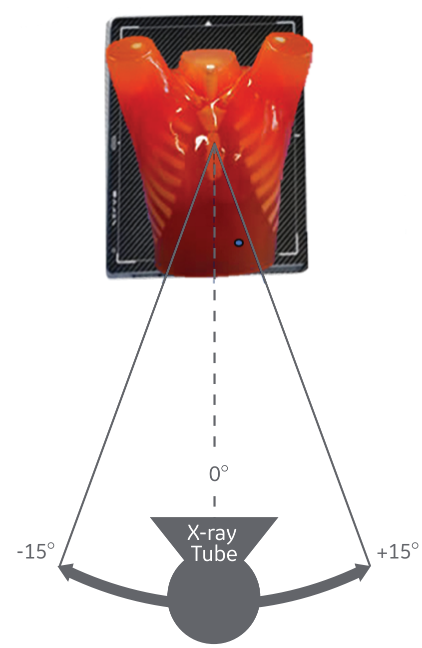


Figure 5: Contrast results measured from images using a chest phantom with an Al disc located in the abdomen, acquired at multiple angles from the central X-ray beam, ranging from -15˚ to 15˚ in 5˚ increments. Contrast ratio equation (eq (2)) defined to measure the contrast of an object relative to the adjacent background. I, average signal intensity in disc. I_b, average signal intensity of background.

AutoGrid Contrast Enhancements

To validate the equivalent contrast enhancement between the grid and AutoGrid, images of a chest phantom were acquired both with and without a grid and the resulting contrast levels were compared.

The chest phantom used was the *Lungman (N1)* phantom (Kyoto Kagagu Co. LTD, Kyoto, Japan) which has supplementary anterior and posterior chest plates to simulate different patient sizes. The phantom is anatomically realistic with varying thicknesses, compositions and anatomical structures. Aluminum discs of varying thicknesses (2-5 mm, 10 mm diameter) were placed within the phantom to properly survey contrast within three regions of a clinical chest exam (lung, heart and abdomen). The phantom and detector were placed in a custom apparatus that easily allowed the attaching and detaching of a grid without shifting the phantom or detector, ensuring that the acquired images were in the same orientation and angle alignment for precise contrast comparisons.

The performance of the grid (at the specified focal distance, Figure 6) and AutoGrid were measured by the improvement in contrast when compared to images acquired without a grid and no further scatter reduction processing.

If acquired with a grid the raw image went through the *Grid Line Reduction* processing to remove grid lines present within the image. If the image was acquired without a grid a copy of the raw image was preserved (no grid comparison) and then the raw image was processed with AutoGrid strength Medium at varying patient sizes. The contrast comparison is performed on the raw images that have only gone through detector corrections to fairly compare the enhancements produced solely by using a grid or AutoGrid. The CR and subsequent CIF were calculated, and their equivalence analyzed (Figure 7). As previously explained, CIF is the ratio of contrast produced through the use of an anti-scatter grid or AutoGrid processing compared to the contrast obtained without a grid. The higher the CIF the greater the improvements in contrast the scatter reduction method provides.[3,4]

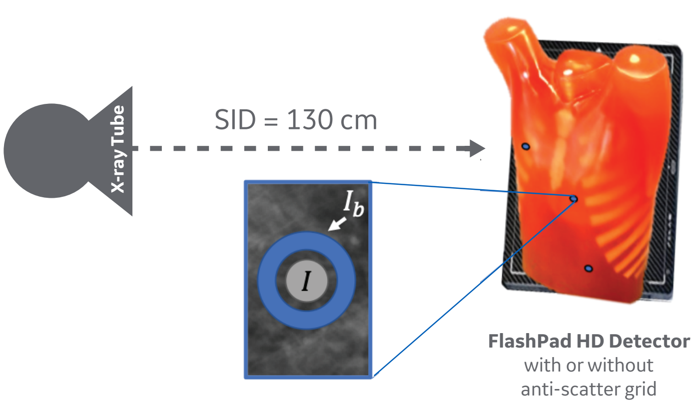


Figure 6: High level experimental setup with the Lungman phantom utilized in the contrast comparisons between images acquired with anti-scatter grids and images acquired without the grid and processed with AutoGrid. Average signal intensity was calculated for each ROI made up of two concentric circles, the first (I) being the aluminum disc and the second (Ib) comprising of adjacent background data.

As can be seen in Figure 7, across patient sizes and anatomical regions, the CIF produced by AutoGrid rivals that of the anti-scatter grid. The plot is specific to data for a grid with an 8:1 ratio and the corresponding AutoGrid strength of Medium. This comparison was repeated with all AutoGrid strengths, and it was confirmed that AutoGrid is capable of reproducing the contrast enhancement obtained when using a physical grid.

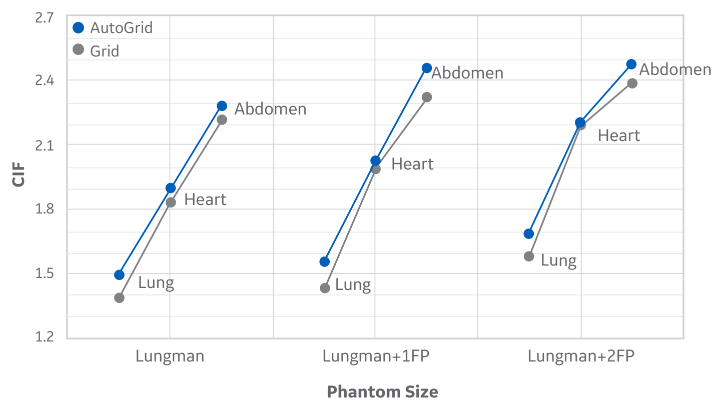


Figure 7: CIF results measured in three distinct anatomical regions within the classic chest exam (lung, heart and abdomen) among various simulated patient sizes (Lungman, Lungman with anterior chest plate attached (Lungman+1FP) and Lungman with anterior and posterior chest plates attached (Lungman+2FP)). The maximum deviation being 8.94% more contrast enhancement in the AutoGrid measurement when compared to the grid.

Clinical Benefits of AutoGrid

This AutoGrid configuration was implemented on five systems at two different hospitals, during product evaluation for approximately five months. During this time, the customers were to integrate the systems fully into their daily routine and use the AutoGrid feature when applicable. Reviews were performed with five radiologists, each specializing in various portions of the anatomy. It was determined through these reviews that **the AutoGrid configuration was appropriate, providing the desired range of contrast enhancement to improve their diagnostic certainty** for the reviewed cases.

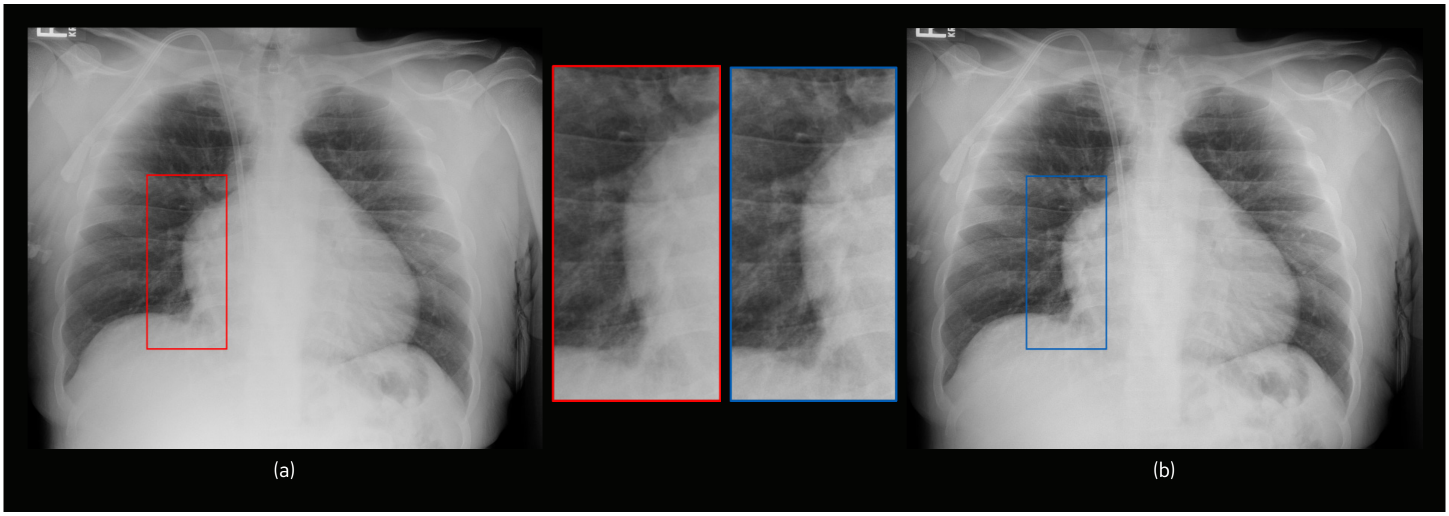


Figure 8: Comparison between (a) image acquired without an anti-scatter grid and (b) AutoGrid processed image.

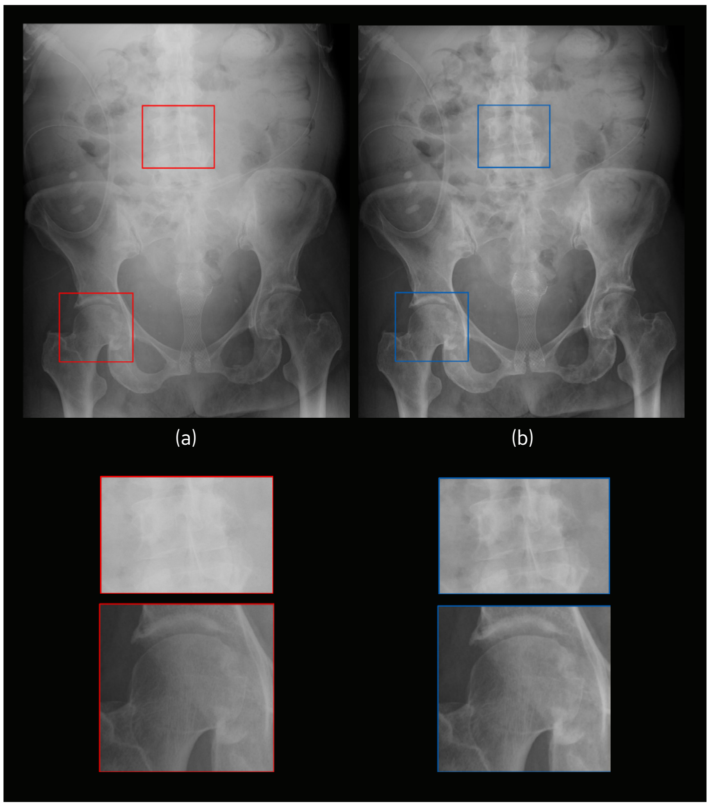


Figure 9: Comparison between (a) image acquired without an anti-scatter grid and (b) AutoGrid processed image.

Conclusion

AutoGrid's dynamically adaptive scatter reduction provides equivalent contrast improvement when compared to images acquired with an anti-scatter grid, while eliminating the performance risks associated with the use of a grid. By limiting errors and retakes, AutoGrid may provide the opportunity to reduce the overall dose delivered to patients during these exams. Utilizing AutoGrid in place of a physical grid not only has the potential to reduce exam times on average by 24%, but it also helps ease financial burden of having to replace the grids as often due to damages that can occur from normal wear and tear. Through both phantom bench testing and clinical experience, it was validated that AutoGrid delivers equivalent IQ for numerous anatomies, views and patient sizes across varying techniques and provides the range of contrast enhancements that radiologists are looking for.

References

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