Enhancement of X-ray Image's Resolution by using fabricated Anti Backscattered Radiation Grids

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Abstract— *This study aims to develop a method for enhancing x-ray image's resolution in radiology department, some fabricated grids with significant capability in reducing backscattered radiation are used to assessment its effectiveness in improving radiographic image resolution. The fabricated anti backscattered grids are designed from different materials with different geometric shapes. Image resolution test tool is exposed to produce x-ray images at different exposure parameters (kVp, mAs). The results of resolution indexes (LP/mm) illustrated remarkable effect of anti backscattered grids in improvement of x-ray image resolution up to 32%, with the use of crossed iron steel grid. Therefore, the effectiveness of fabricated grids in enhancing image resolution is dependent on the grid's material and design, as well as the radiation exposure parameters.*

Keywords— Resolution, Anti-backscattered grid, X-ray, Image quality.

I. INTRODUCTION

X-ray image is widely used in medical diagnosis; it is considered an important technique for the majority of radiological examinations (Huang, 2011). The value of x-ray image details depends on image's resolution. Therefore, x-ray image's resolution is a significant characteristic of radiograph quality which could be used to evaluate the capability of radiographic system in imaging two separate objects or tissues and visually distinguish one from the other. Medical imaging system with higher spatial resolution can demonstrate the presence of smaller objects in the produced image (Huda and Abrahams, 2015).

Two common ways used to evaluate the resolution properties of an imaging system are the line spread function and the modulation transfer function. Spatial resolution throughout medical imaging systems is described quantitatively by the response of the imaging system to a test device. The test pattern in X-ray radiography is called a line-pair per mm, and consists of highly absorbing lead lines with varying widths separated by interspaces of equal size between lines (Bushong, 2013; Bushberg et al., 2012; Guy and Dominic, 2005).

Spatial resolution is expressed by the number of line pairs per millimeter (lp/mm) that appear in the x-ray's image. The measure of resolution depends on the difference in contrast between black and white lines recorded from the test pattern. The higher of this number refer to the better of the spatial resolution and smaller of object that can be imaged clearly (Huda and Abrahams, 2015; Bushong, 2013; Bushberg et al., 2012; Guy and Dominic, 2005).

Huda and Abrahams (2015) described the essential characteristics of spatial resolution and reported some factors influenced the sharpness of radiographic image including the size of the source of x-rays (focal spot), the degree of photons scatter, the physical properties of the x-ray detector system (area and thickness), the motion blur, and the image processing.

II. EXPERIMENTS

2.1 Equipments

Some equipments are used in this study (Figure 1) which included two X-ray units (stationary and mobile), resolution test tool (PTW FREIBURG) which is a parallel lead strips separated by a distance equal to the width of the strips, radiographic image processor (Autoprocessor, Minolta SRX-101A). Some anti-backscattered grids are fabricated in this study in order to reduce backscattered radiation which in turn affects the X-ray image resolution. These grids constructed from various material (iron steel and aluminum) with different geometric designs (crossed and linear) as shown in Figure 2.

MOBILE X-RAY MACHINE (TOSHIBA IME-100L)

STATIONARY X-RAY MACHINE (TOSHIBA KXO-5OS)

X-RAY IMAGE PROCESSOR (SRX-101A)

RESOLUTION TEST TOOL (PTW- FREIBURG)

FIGURE 1: SOME EQUIPMENT OPERATED IN THE MEASUREMENTS

LINEAR GRID

CROSSED GRID

FIGURE 2: THE FABRICATED ANTI-BACKSCATTERED GRIDS

2.2 Procedures

To estimate x-ray image resolution, the quality control test tool of resolution (PTW FREIBURG) is utilized with a single exposure on X-ray film. For each radiation exposure, film screen combination is placed on the patient table of x-ray system. The resolution test tool is placed over film screen combination, the collimator is adjusted to covers exactly the test tool. The distance between the film and the focal spot of x-ray tube (FFD) is set to 100 cm.

Several images were produced with various exposure parameters (kVp and mAs). After the film processing, the image resolution of x-ray film is determined and compared with the real test tool.

Assessment of image resolution index is carried out by estimating the line width and separation distance in terms of line pairs (Lp) per unit distance (millimeters) (Lp/mm). One line pair consists of one lead strip and adjacent separation space (Sezdi, 2011). The experiments in this study are conducted in the Biophysics laboratory, School of Physics, University of Science Malaysia (USM), Malaysia

III. RESULTS AND DISCUSSION

Numbers of x-ray images were produced with different setups and exposure parameters. For all radiograph, resolution indexes expressed in LP/mm were estimated and evaluated as it is presented in the following.

3.1 Radiographic image resolution for different x-ray units

In this part, two x-ray units (stationary and mobile) were used to produce radiographs at optimum exposure parameter values (70 kVp - 20 mAs), and 100 cm FDD. Figure 3 showed the image resolution indices for radiographic films exposed by different x-ray units and revealed the differences between image resolution indices with and without using anti backscattered grid under the radiographic film screen combination (film cassette).

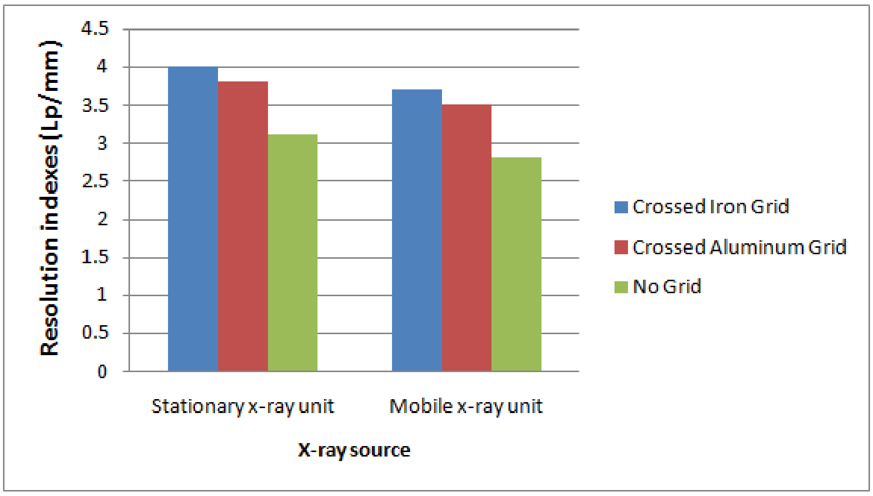

FIGURE 3: IMAGE RESOLUTION INDEX (Lp/mm) FOR DIFFERENT X-RAY UNITS

More resolution index (Lp/mm) means better image resolution on radiographic film. The variation in the number of line pairs per millimeter (LP/mm) refers to the effect of backscattered radiation on x-ray image resolution. The results of image resolution in this study are in agreement with Park et al (2012) who found that the nature of increasing resolution may come from reducing backscattered radiation.

Utilizing both anti-backscattered grids provided more image's resolution compared to resolution indeces without using anti-backscattered grids. To assess the effect of different grids on enhancement of image resolution, the percentages of image resolution increases are calculated for various grids and illustrated in Figure 4.

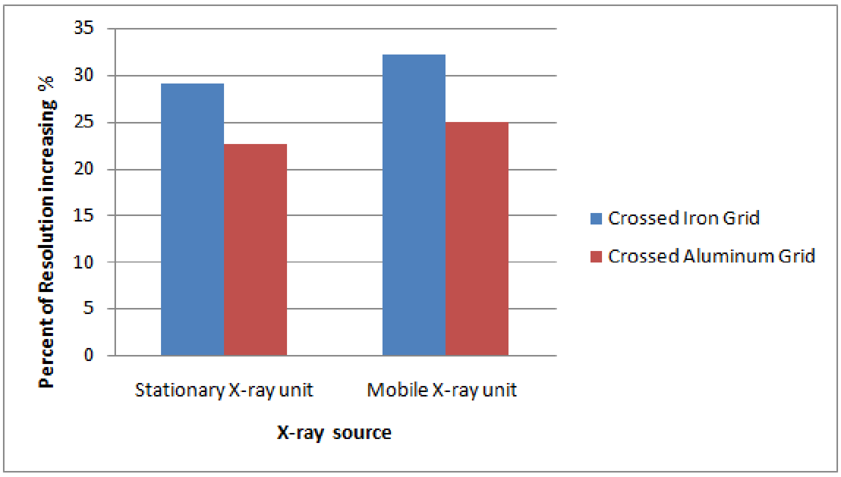

FIGURE 4: RESOLUTION INDEX INCREASING PERCENTAGES WITH DIFFERENT X-RAY UNITS

Figure 4 illustrated the effectiveness of anti-backscattered grids for different x-ray units, these increments for image resolution indices caused by utilizing anti backscattered grids under exposed film screen combination during x-ray image acquisition, both anti-backscattered grids showed advantages in improvement of radiographic image' resolution.

With reference to grid's type, For both x-ray units, better image resolution can be achieved by using fabricated crossed iron grid because of its better capability in attenuating backscattered radiation which affect on image resolution. The percentages of increase in image resolution due to using fabricated anti-backscattered iron grids improved about 29.03% and 32.14 % for stationary and mobile x-ray units respectively.

3.2 Radiographic image resolution at different x-rays energy (kVp)

Different fabricated anti-backscattered grids according to its material and geometrical design are used at parameter setting values of 20 mAs- 100 cm FDD, and different x-ray tube voltage (kVp). Also, this procedure evaluated the effectiveness of anti-backscattered grids at various (kVp) on the image resolution. Figure 5 shows the resolution indices expressed in (LP/mm) for some radiographic images at different kVp with and without using anti-backscattered grids, and described the effect of grid type (which depend on grid's material and geometrical design) on image resolution.

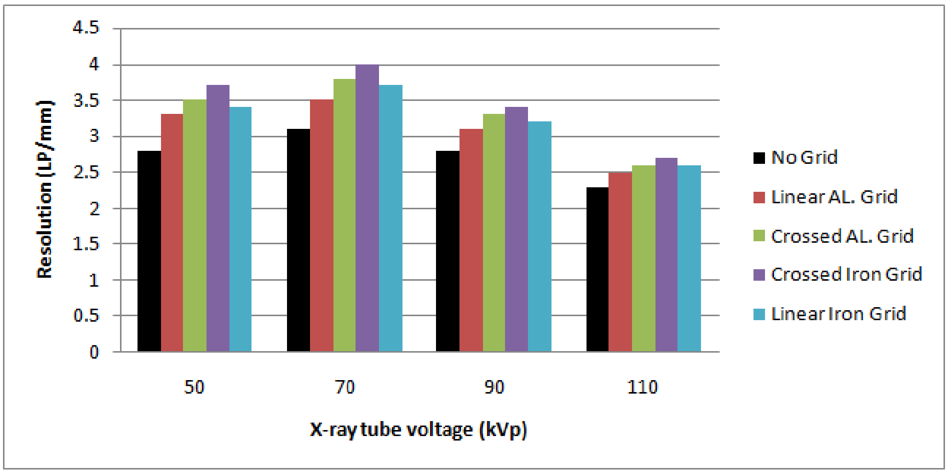

FIGURE 5: IMAGE RESOLUTION INDEX (Lp/mm) WITH DIFFERENT kVp

During x-ray imaging some remnant photons with scattering angle reflect back to film screen after encountering patient table or bucky, more backscattered photons deteriorating the image resolution.

Best image resolution can be obtained at relatively lower kVp, the best resolution indices were achieved at 70 kVp. By increasing peak tube voltage more than 70 kVp, image's resolution is reduced for all setups. This result is in agreement with Gui et al. (2013) and Tavares et al. (2015) who reported that the tendency for image quality degradation when x-ray tube voltage increases. This can be explained with the effect of primary photons energy on the increase of backscattered radiation.

The resolution indexes were increased as a result of using fabricated anti-backscattered grids. Figure 5 illustrated the different capabilities of anti-backscattered grids in improving image resolution, as a result of grid's effectiveness in reducing backscattered photons which in turn trapped by grid's trips and plate.

These results revealed that, fabricated anti-backscattered grids play an important role in the improvement of image quality by increasing the resolution index (LP/mm) at various x-ray tube voltages.

With reference to the grid's type, the best resolution can be achieved by using crossed iron grid compared to other grids at different kVp. With lower tube voltage, the enhancement of radiograph resolution caused by using anti-backscattered grids presented best values comparing with higher kVp because the effect of photons' energy.

To assess the different capabilities of anti-backscattered grids, the percentages of images resolution indexes were calculated at different utilized kVp. Figure 6 illustrates the effectiveness of anti-backscattered grids at different energy of x-rays by figuring the increment percentages of resolution as a function of kVp.

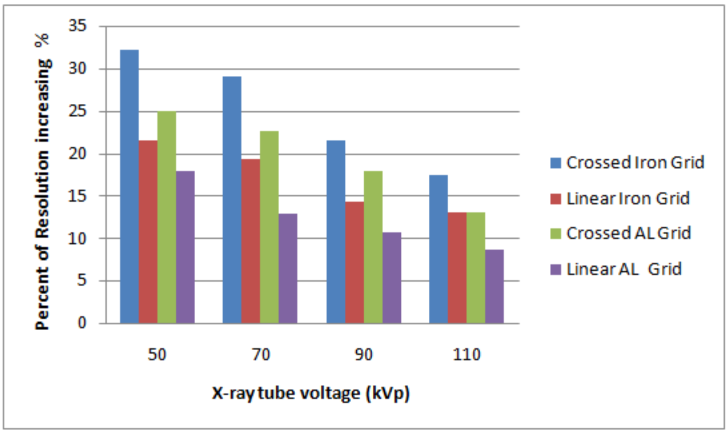

FIGURE 6: RESOLUTION ENHANCEMENT PERCENTAGES WITH ANTI-BACKSCATTERED GRIDS

Figure 6 showed the capabilities of various grids in enhancement of radiographic image resolution as a function of x-ray tube voltage (kVp).The capabilities of grids in enhancement of image resolution exhibited best values at lower x-ray tube voltage up to about 32.14 % at 50 kVp.

The differences in resolution increment are referred to anti-backscattered grid type according to grid's material and geometrical design. Figure 6 showed that, crossed iron grid has best value in improving image resolution compared to other anti-backscattered grids for different kVp. This advantage raised from the capability of iron material in reducing backscattered radiation at different energy, attenuation of backscattered x-ray by crossed iron grid controlled by the atomic number and density for iron, as well as geometrical design of grid. In summary, these results showed the directly proportionality between reducing backscattered radiation and radiographic image resolution.

In summary, utilizing fabricated anti backscattered grids proved remarkable effectiveness in the improvement of image quality by increasing the resolution index (LP/mm).

3.3 Effectiveness of anti-backscattered grids in enhancement of image resolution at optimum energy

Figure 7 illustrated the effectiveness of different types of anti-backscattered grids (according to grid's material and geometrical design) in improvement of x-ray image resolution at optimum energy for resolution test tool imaging (70 kVp).

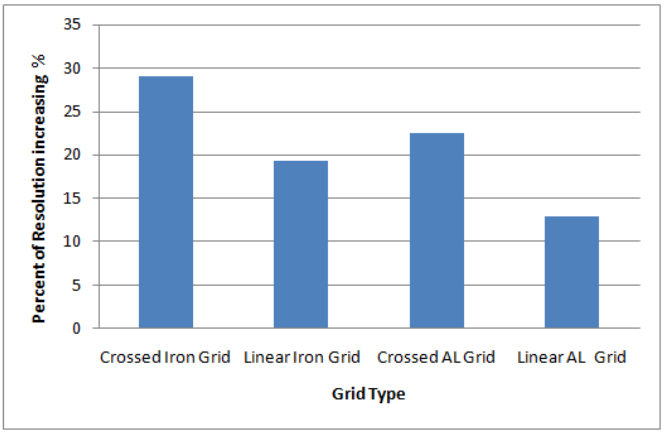

FIGURE 7: EFFECTIVENESS OF ANTI-BACKSCATTERED GRIDS AT OPTIMUM ENERGY (70 kVp)

Anti-backscattered grids have different capabilities in improving image resolution according to grid's effectiveness in reducing backscattered radiation; the effectiveness of grid depends to the capability of grid's strips and plates in absorbing and trapping backscattered photons.

Figure 7 demonstrated the dependence of radiograph resolution increment on the type of utilizing anti-backscattered grid according to the grid's material and geometrical design. The differences in gained resolution index refer to grid type; the best resolution can be obtained by using crossed iron grid comparing with other grids types because its ability in reducing more backscattered x-ray photons.

In summary, crossed iron grid has best value in improvement of image resolution at different x-rays energy, this advantage raised from the capability of iron material in reducing backscattered radiation with different energy. The attenuation of backscattered x-ray by crossed iron grid controlled by the atomic number and density of iron and geometrical design of grid. These results showed the directly proportionality between reducing of backscattered radiation and radiographic image resolution.

3.4 Radiographic image resolution variation with X-ray intensity (mAs)

This part investigated the radiographic image resolution at different x-ray tube current and exposure time (mAs), as well as the capability of anti backscattered grids on enhancement of image resolution at different mAs. This investigation was carried out by calculating the increment percentages of resolution index for different mAs. The exposure parameters setting values were 70kVp - 100 cm FDD.

Figure 8 demonstrated the radiographic image resolution expressed in (LP/mm) as a function of exposure quantity (mAs) with and without using anti-backscattered grid under film screen compination during acquisition of radiographic image.

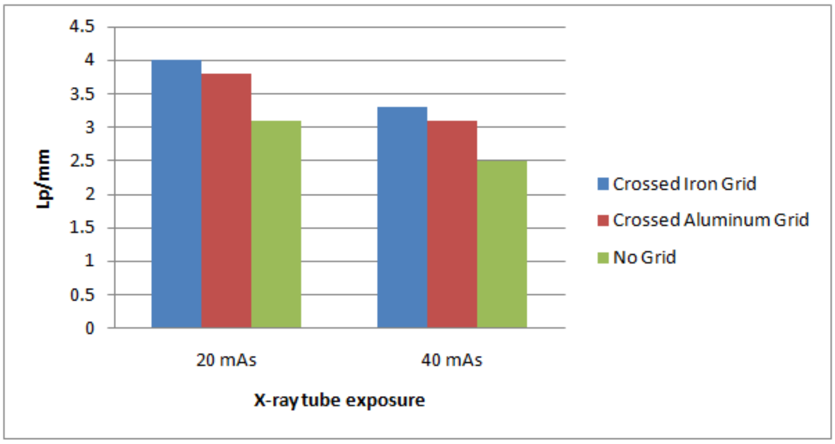

FIGURE 8: IMAGE RESOLUTION INDEX (Lp/mm) AT DIFFERENT mAs

Figure 8 demonstrated the radiographic image resolution at different exposure intensity (mAs).The better image resolution was obtained at lower exposure intensity (20 mAs) compared to higher exposure quantity (40 mAs) due to the increase of x-ray photon number by increasing mAs, which may affect produced image's resolution as well as the probability of backscattered radiation presence. Therefore, with relatively low radiation exposure, excellent image quality can be obtained; this result is in agreement with (Zhang et al., 2011 &Baksi, 2012).

The best image resolution can be obtained by using fabricated backscattered grids. To evaluate the capabilities of different anti-backscattered grid in enhancement of image resolution at different mAs; the increment percentages for resolution index are calculated and illustrated in Figure 9.

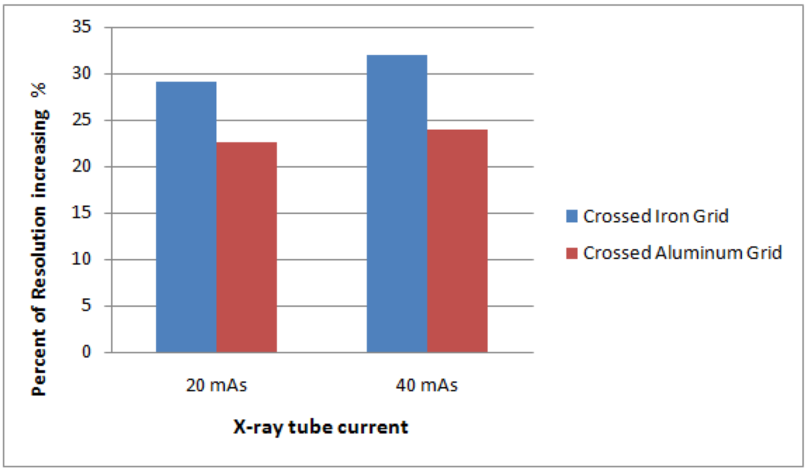

FIGURE 9: RESOLUTION INCREASING PERCENTAGES AT DIFFERENT (mAs)

Figure 9 showed that the capabilities of fabricated anti-backscattered grids in increasing image resolution were exhibited best values at higher x-ray tube current (mAs). This result can be explained due to the statistic nature of resolution indexes, and the direct proportionality between x-ray tube current and x-ray photons' intensity.

The resolution index increased by reducing mAs. Also, the percentage of image resolution improvement recorded by using crossed iron grid is more than that recorded by using crossed Aluminum grid.

In summary, the best resolution index can be achieved by using crossed iron grid under film cassette during exposure with lower radiation intensity (mAs). With reference to grid type, crossed iron grid proved best value in the percentage of image resolution improvement for both utilized values of mAs. Hence the best resolution index can be achieved by using crossed iron grid under film screen combination with relatively lower radiation intensity (20 mAs).

IV. CONCLUSION

Radiographic image resolution can be increased by utilizing anti back scattered radiation grids under film screen combination during exposure. All fabricated anti back scattered grids proved its capability in reducing back scattered radiation which enhance image resolution. The capability of anti backscattered grids in improvement of image resolution depends on grid's material and geometrical design, as well as exposure parameters (kVp, and mAs), the best enhancement of image resolution can be obtained by using crossed iron grid with relatively lower kVp and mAs values.

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