APPLICATION OF CONTRAST IMPROVEMENT METHODS FOR CORPULENT PATIENTS UNDERGOING CHEST SCREENING*

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Abstract. *Annual chest screening in Ukraine is a needed diagnostic procedure due to high level of tuberculosis, and it essentially contributes to the collective effective dose. Particularly this problem is actual for stout patients, who receive a higher exposure dose during chest screening, compared to average patients. This is done to obtain X-ray images with proper visual contrast and accuracy. In the present study, the results obtained with the application of anti-scatter grid technique, common for clinical fluorography examination, were compared to results obtained by image processing, as an improving visual contrast method for stout patients. In the present study, image processing increased the contrast value of test-object in the range of 2.0-2.73 times without ED increase; image processing after signal filtration with anti-scatter grid demonstrated the increase of image contrast 3 times in average along with the ED increase in Bucky factor to the 3.1-3.2.*

Key words: *Exposure dose, contrast of X-ray images, digital fluorography, image processing*

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1. Introduction

In Ukraine chest screenings are performed annually and significantly contribute to effective collective dose of adult population. This problem is particularly actual for stout patients, whose X-ray examination requires higher exposure dose to obtain diagnostic images with proper contrast and resolution. The photons, scattered by the human body, decrease the signal-to-noise ratio and reduce the chance of finding pathology in the X-ray image. The image quality can be improved by application of high or low tube potential technique. Both of these techniques have advantages and disadvantages. As it was shown in [1,2], usage of high potential technique can produce not only high energy transmitter photons, but also high energy scattered photons. Such photons can reach the adjacent or remote organs and tissues. The level of noise rises with the body thickness. In routine clinic practice, the application of anti-scatter grids with various grid ratios is effective method to remove scatter photons and obtain good quality images. However, unfortunately the anti-scatter device usage requires increase of the exposure dose in Bucky factor (in several times). For this reason the usage of high potential technique with anti-scatter grid is not recommended [1]. The stout patient examination requires higher energy photons (tube potential increase) or its bigger quantity (tube current increase). The disadvantage of low potential technique is negative biological effect of the low energy photons absorbed in soft tissues due to their weak penetration ability. But the optimal choice of technical parameters during the performing of high potential technique, with additional aluminum and copper filters, proper focus to film distance and air gap method application were demonstrated to be much more effective in reducing the exposure dose compared to anti-scatter grid application [3,4,5]. Other methods which allow the improvement of digital image contrast without dose increase include noise reduction algorithm and super-resolution technique [6]. In addition, the visibility of the pathological structure in the digital X-ray image can be improved by a post processing [7,8,9,10].

In the present study we researched the optimal application of the anti-scatter grid and digital software processing (DSP) in the context of exposure dose reduction for stout patients.

2. Methods and materials

2.1. The Digital X-ray System

The simulation of clinical chest screening was performed on the water phantom. The images were obtained by the digital X-ray unit at "Teleoptic PRA" Ltd laboratory, Kyiv, Ukraine. The digital X-ray image processing was performed with special software ContextVisionCVIE-teleoptic-XR2-ADI, which is based on the principle of non-linear signal filtering.

The fluorography system generating photons (X-ray tube by Toshiba) was equipped with X-ray dosimeter (Radcal Corporation, type 2026 Radiation Monitor) with ionizing chamber (20X-60) installed behind the anti-scatter grid. The figure 1 shows the experimental scheme. The measurements were performed at screening tube potential 81 kV, standard for the chest,

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and focus-to-source distance 120 cm. The scatter photons were removed by SOYEE 11104 anti-scatter grid with 10:1 ratio, 51 lines/cm and focus distance 120 cm. The X-ray images were obtained with digital fluorography receiver (Iona–R4000 by Teleoptic PRA Ltd). The image resolution was measured with X-ray test pattern (range: 1.0-10.0 l.p./mm). The obtained X-ray image was processed by software ContextVision CVIE [11].

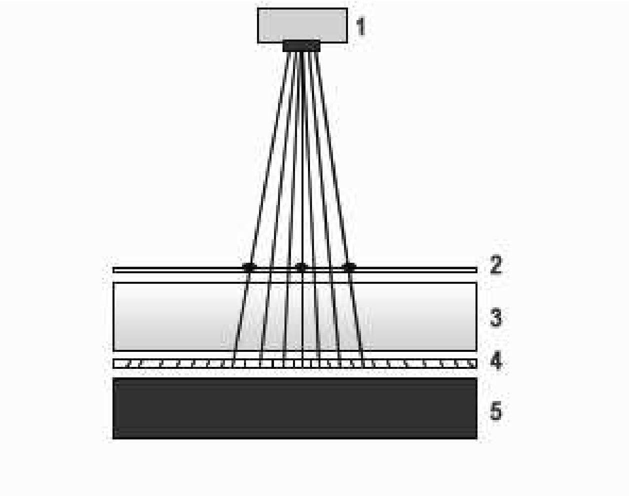

Figure 1. The experimental scheme: (1) X-ray tube, (2) plate with aluminum test-objects, (3) the water chest phantom, (4) anti-scatter grid, (5) digital receiver.

2.2. The Phantom Study

In the experiments, the patient chest was simulated by the water phantom. The phantom is a box with variable thickness from 9 to 21 cm. During the experiments the phantom thicknesses was changed gradually (by 3 cm of the water). According to clinical standards, the water layer in phantom more than 10 cm thick corresponds to the patient with body mass index more than average. During the experiments, phantom thickness equaled to stout patient was gradually changed in a range of 9 to 21 cm.

2.3. The Visual X-ray Image Contrast

The visual contrast of the test-object was set as an evaluative factor for X-ray image quality improvement. The test-object was an aluminum disk, 0.5 mm thick and 15 mm in diameter. The contrast, *C*, was calculated:

$$C = B_b - B_o / B_b - B_n , \qquad (1)$$

B_o – an averaged brightness of the object in image, B_b – an averaged background brightness, B_n – an averaged background brightness value (X-ray tube was switched off). In the experiments, B_n equaled to 1000 units of brightness scale. The brightness of image background was calculated using averaged brightness data over all pixels within the area around the test-object.

3. Results and discussion

The phantom study results obtained under varied experimental conditions with application of anti-scatter device and software processing are shown in Table 1. The 5% contrast threshold of the test-object image was set as a criterion of proper image contrast achievement. Such contrast threshold is considered to be crucial for visual revealing of chest organs pathology. During the experiment, the operating parameters such as tube current, exposure time (at constant tube potential) were selected in optimizing manner.

The measurements performed on 9 cm thick phantom without usage of anti-scatter grid but with the next application of software processing demonstrated achievement of 5% visual threshold (Figure 2).

Table 1. The contrast values comparison analysis of images obtained with application of anti-scatter grid and software processing (constant tube potential 81 kV). [1]*I* – tube current; [2]*t* – exposure time; [3]*ED* – exposure dose; [4]*C* – image contrast value; [5]C_{sp} – image contrast value after software processing

Water layer, cm	Grid application	[1]I, mA	[2]t, ms	[3]ED, mGy	Bucky factor	Resolution, p.l./mm	[4]C, %	[5]Csp, %
9	no grid	320	80	1.39		3.1	2.2	5.0
9	grid	320	150	2.32	1.2	3.1	3.6	8.6
12	no grid	160	100	0.84		3.1	1.5	4.1
12	grid	320	160	2.70	3.2	3.1	2.6	7.5
15	no grid	320	80	1.39		3.1	0.9	2.8
15	grid	320	250	4.32	3.1	3.1	2.0	6.2
18	no grid	500	80	2.27		2.7	0.5	2.0
18	grid	400	400	8.23	3.6	2.7	1.5	4.8
21	no grid	500	160	4.81		2.5	0.5	1.0
21	grid	320	800	15.36	3.2	2.5	1.6	3.2

The usage of anti-scatter grid leads to the increase of ED in Bucky factor 3.1 on the obtained images with minimal visual quality. The contrast value of test-objects on chest phantom by 12 cm thick X-ray images obtained without anti-scatter grid application was 1.5%, after DSP – 4.1% and the exposure dose (*ED*) was

0.84 mGy. The application of anti-scatter grid allowed the reception of images with 2.6% contrast value but the exposure dose increased in Bucky factor 3.2, *ED* = 2.70 mGy. After additional DSP it achieved the visual threshold of 5%.

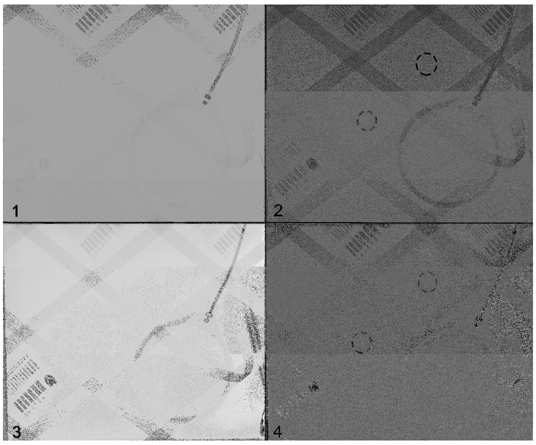

Figure 2. X-ray images of test-objects obtained for 9 cm thickness of water phantom: without usage of anti-scatter grid before software processing (1) and after (2); with anti-scatter grid before software processing (3) and after (4).

The test-objects' contrast value on the 15 cm thick water phantom X-ray images under minimized working parameters equaled 0.9%, after DSP it increased up to 2.8%, *ED* = 1.39 mGy. The anti-scatter grid application increased the test-object image contrast value to 2.0% (with *ED* rise in Bucky factor 3.1 equaled 4.32 mGy) and the next additional DSP improved it up to 6.2%, reaching the visual contrast threshold. The experimental data demonstrated the successful results in obtaining of visual test-object image contrast using digital software processing (figure 3).

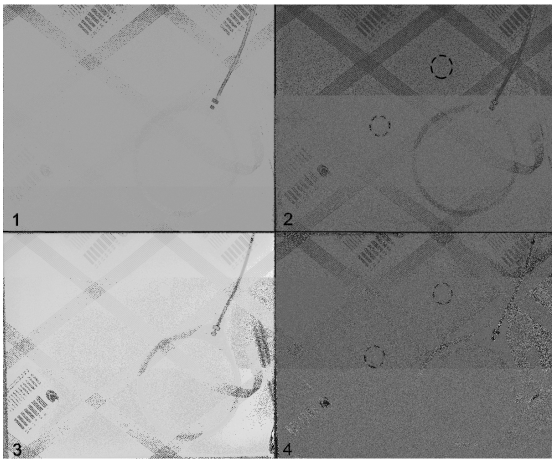

Figure 3. X-ray images of test-objects obtained for 15 cm thickness of water phantom: without usage of anti-scatter grid before software processing (1) and after (2); with anti-scatter grid before software processing (3) and after (4).

The next variation of the phantom thickness to 18 and 21 cm demonstrated the almost equal quality image improvement possibilities of anti-scatter device and digital processing on the one hand, and both methods combining efficacy on the others. It should be noted that the fluorographic system resolution decreased from 3.2 p.l./mm to 2.5 p.l./mm. As shown in figure 4, the visual test-object image contrast decreases along with the phantom thickness variation. For the 12 cm phantom water layer, the anti-scatter device and the digital image processing improved the image contrast in 1.7 and 2.7 times respectively. These results show that the digital processing improves the contrast value in 1.6 times compared to the anti-scatter grid application while the exposure dose was 3.2 times less. The efficacies of the anti-scatter device and digital processing decreased along with rise of phantom thickness (15-21 cm) and demonstrated almost the same results in test-object image contrast improvement. The image visual contrast value obtained with anti-scatter grid application was successfully increased up to visual threshold by usage of DSP (15 and 18 cm).

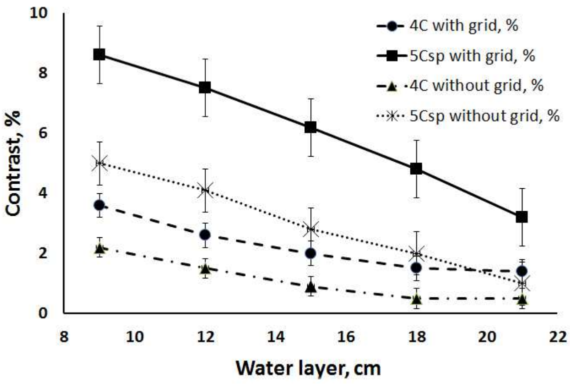

Figure 4. The graph shows the change in contrast value of test-object image against water phantom thickness under conditions of software processing and anti-scatter grid separate or simultaneous application.

The obtained experimental data shows the effectiveness of DSP compared to anti-scatter device in the achievement of visual threshold without delivering high exposure dose to the patient. However, the problem of digital processing application for image quality improvement without the previous anti-scattered grid signal filtering is based on the physical principles of X-ray image obtaining. The anti-scatter device allows increasing the signal-to-noise ratio on the images via removing photons scattered by patient's body. For this reason, the anti-scatter device cannot be replaced by software processing in case of patient with higher body thickness due to the image artifacts. The reasonable combining of anti-scatter application and additional DSP allows optimizing the exposure dose and receiving the images with a proper visual contrast.

4. Conclusion

The X-ray images with visual contrast value of 5% were successfully obtained using the anti-scatter grid and the software processing under minimal operating parameters forming exposure dose delivered to the patient.

The experimental data shows the possibilities of the software processing to increase the test-object contrast value in a range of 2.0-2.73 times without *ED* increase. The digitally processed image after signal filtration with anti-scatter grid demonstrated the increase of image contrast in an average of 3 times along with the *ED* increase in Bucky factor 3.1-3.2.

The high exposure dose delivering to the stout patient during the fluorography chest screening can be significantly reduced due to reasonable operating parameters selection, anti-scatter grid application and software processing combining.

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