Economic Evaluation of Computed Radiography Comparing to Film Method in Quality Control of General X-ray Machine at Phramongkutklao Hospital

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Objective: *To evaluate the efficiency of quality control performance for a general x-ray machine between computed radiography (CR) and film method.*
Material and Method: *CR performance as a quality control method for a general x-ray machine was compared to the film method. Two raters independently analyzed the result of quality control from both methods. Economic evaluation was performed by cost-minimization analysis. All data (result for quality control and cost) were collected from Phramongkutklao Hospital from August 2007 to January 2008.*
Result: *Quality control performances of a general x-ray machine by using CR and film method were equivalent. Interobserver agreement for analysis of quality control measurements was almost perfect. Unit cost, test performance time, radiation dose for quality control by CR were less than the film method (p < 0.001).*
Conclusion: *The performances of quality control of a general x-ray machine done by the CR method are more efficient than the film method. Using the CR method for quality control performance of the general x-ray machines will save cost enormously.*

Keywords: *Economic evaluation, Quality control, Computed radiography, Film*

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The general x-ray machine is the basic equipment that all hospitals use for diagnostic purposes; however, the machine has many elements, each of which is subject to change with time. To produce a single radiograph, the kilo voltage (kVp), milliampere (mA), time, collimators, focal spot size, grid and image receptor are important elements that requires appropriate function[1]. Each element in the imaging chain can vary such that the image quality may be poor that is the most important cause of incorrect diagnosis. In addition, if there is repeated examination, radiation exposure to the patient and to the technician will increase. Moreover, patient's waiting time and the operation cost of the hospital will increase as well.

Consequently, it is essential to quality control on all of the elements in general x-ray machines comprehensively and routinely. Quality control of each element uses different equipment. Now, four elements use film, film processing and chemicals to do for the quality control are collimator alignment test, milliampere-sec (mAs) reciprocity test, grid alignment test and determination of focal spot size (referenced by the Nation Council on Radiation Protection and measurement (NCRP) No.99[1].

The aim of collimator alignment testing is to check that the light field coincides with the x-ray field. If the x-ray field does not coincide with the light field,

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this may cause an error[2]. The objective of mAs reciprocity test was to check the consistency of the mA station. Grid alignment test is used to test alignment of the radiograph grid with respect to the central ray of the x-ray tube. The results of such a misalignment increase patient dose and reduce image contrast. The aim of determination of focal spot size is to measure the effective focal spot size of the x-ray tube to compare with focal spot size acceptance tolerance limits by the National Electrical Manufacturer's Association (NEMA). The size of the x-ray tube focal spot affects the final radiographic image quality. If the focal spot is too long, the quality of the image will be degraded.

Computed radiography (CR) or digital imaging system[3,4] is well accepted in radiological departments worldwide. It has many advantages over conventional screen-film system. The photostimulable phosphor plate is reusable more than 45,000 times, unlike film. In addition, the film system requires handling of film for viewing, area for archiving, hazardous chemicals and time for transferring to other departments[5,6]. It is interesting to evaluate the efficiency of CR as a quality control of four elements of the general x-ray machine in place of the film method.

From literature review, the majority of these papers studied the comparative reject rate analysis in human's conventional screen-film radiography, CR and comparative clinical images of each human organ in both systems that showed the superiority of the CR to conventional film[3,7-10]. The studies were undertaken to investigate and compare the reject rate between conventional screen-film radiography and CR in the same radiology department that showed the using of CR was significantly lower than conventional radiography[3,7-9]. The evaluation of bilateral hand images from 50 patients were scored independently by six musculoskeletal radiologists, in each case one hand was imaged with a conventional screen-film and the other with CR that showed the using of CR was statistical significance better than conventional screen-film[10]. However, little information is known on using CR for quality control of the general x-ray machine.

The present study is designed to evaluate whether quality control in four elements of a general x-ray machine at Phramongkutklao Hospital between using CR is similar to the film method. In addition, the authors compared costs, time and radiation dose of both methods.

The study comprises of two parts; the first is the comparative of result for quality control of two alternatives between CR and film method. The second is economic evaluation using cost-minimization analysis. All Data were collected from Phramongkutklao Hospital, from August 1, 2007 to January 31, 2008.

The First Part: The Comparative of Result for Quality Control of Two Alternatives

Material and Method

Equipment required

The Kodak computed radiography systems 800; Kodak X-Omit screen-film and Kodak portal pack film for localization imaging (PPL) were used for quality control of a general x-ray machine that it was randomly selected by using a simple random sampling method from total of general x-ray machines at Radiology Department, Phramonkutklao Hospital.

Procedure

a) Four elements of a general x-ray machine (Toshiba model KXO-80G) were checked by using CR and film that procedure were referred by NCRP No. 99 and Radiation Measurements Inc. (RMI) quality assurance handbook. Testing of both methods used the same procedure, the only difference is that CR method used imaging plate in the cassette while film method used film in the cassette.

b) Sample size determination for equivalent test of result of quality control in both methods was determined by using formula for two-related samples with continuous outcome[11]. With the two-tailed test of 0.05 significant level, 90% of power, standard deviation of difference in both methods 0.221 and usage of equivalence for 0.1 giving number of 52 pairs of both methods in each checking element of a general x-ray machine.

c) Measurement of radiation dose used in each checking element of both methods by using radiation dose meter for calculation of the radiation dose ratio that was compared between film and CR method.

d) Record time consumed in each checking element of both methods by two raters.

Measurement of result of quality control

The measurement was comprised of four parts. These were:

a) Collimator alignment test: two independent raters measured all four sides for maximum error of the light field with x-ray field that they measured at the same position of both methods as shown in Fig. 1. Film method, measured on viewing box luminance while CR method, measured on computer with image viewer software. The authors determined equivalence limit of measurement of error sum of both width sides (C + D) and error sum of both long sides (A + B) of film and CR method is 0.2 cm.

b) mAs reciprocity test: The consistency of the mA stations can be checked by looking at the densities of the step wedge pattern images. Using the same kVp and mAs value, but vary time and mA setting for each exposure. Fig. 2A is radiograph that it is exposed with 50 kVp, 100 mA, 40 msec while Fig. 2B is radiograph that it is exposed with 50 kVp, 200 mA, 20 msec. The mA is satisfactory if the corresponding steps appear the same density.

For film methods, two independent raters measured optical density of 11 corresponding steps using the X-Rite 341 densitometer while CR method, measured on computer with a public domain Java program Image J[12]. Because unit of density is not a like, film is optical density (OD) but CR is pixel value so, evaluation of equivalence test, the authors must find the relationship between optical density and pixel value that is a great finding, through exposed radiation on 21 step wedges with film and CR method using the same exposure setting, measurement densities on film of each step using X-Rite 341 and digital image using program Image J. Fit cubic curve estimation, giving optical density (OD) is a dependent variable while pixel value is an independent variable. This curve estimation is illustrated in Fig. 3. Therefore, pixel value can be converted to the optical density for equivalence test. The authors determine equivalence limit of measurement of difference of corresponding step's density of both methods is ± 0.1 optical density.

c) Grid alignment test: If the grid is properly aligned, the middle hole should display the maximum density. The density in the other four holes should fall off symmetrically about the middle hole. Independent two raters measured the density all five holes as shown in Fig. 4.

For film method, X-Rite 341 densitometer was used for measurement, CR method, measured on computer with program Image J. According to the problem about different unit of both methods, the authors convert pixel value to the optical density for equivalence test by using fit quadratic curve estimation as same as the test of mAs reciprocity. If the range of difference in outcome is equal to 1, both methods will be concluded to be equivalent while the range of 0 will be set for non-equivalent. Therefore, the determination of equivalence limit of both methods is ± 10% or ± 0.1.

d) Determination of focal spot sizes: In the present study, focal sizes were measured by using star technique. Independent two raters measured the diameter of blur distance at the width direction and length direction, supposed they are Dw and Dl (Fig. 5). Film method measured on viewing box luminance while CR method measured on computer with DICOM image viewer. Dw was calculated for finding focal

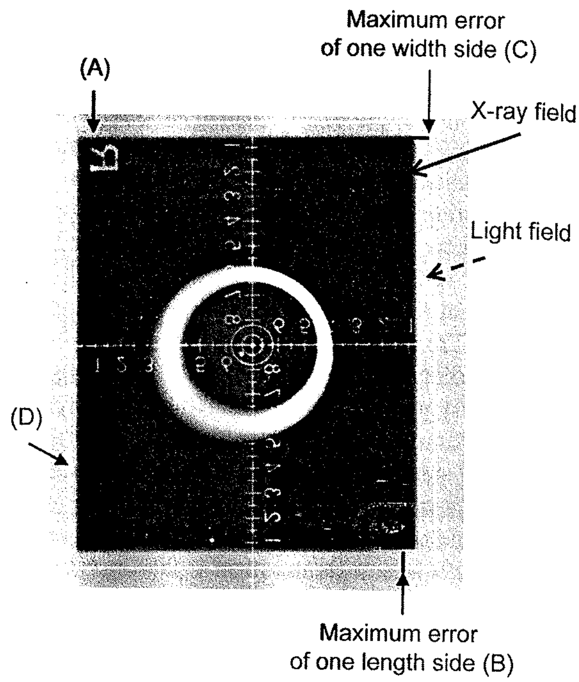

Fig. 1 Radiograph showing the result of test conducted for coincidence of light field and X-ray field that the maximum of distant between edges of both fields is error of collimator that is measured all four sides

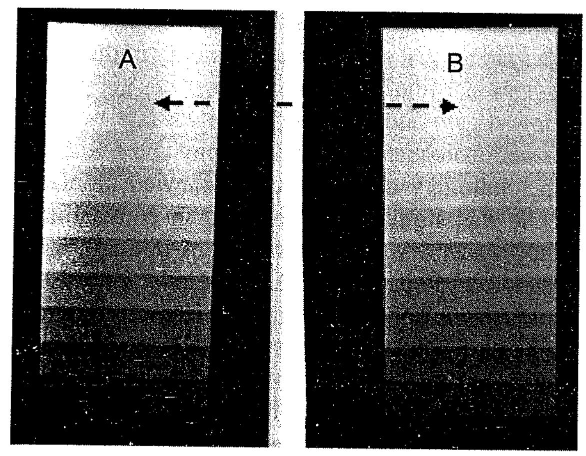

Fig. 2 Radiograph showing the result of mAs reciprocity test. Dashed line is the corresponding steps

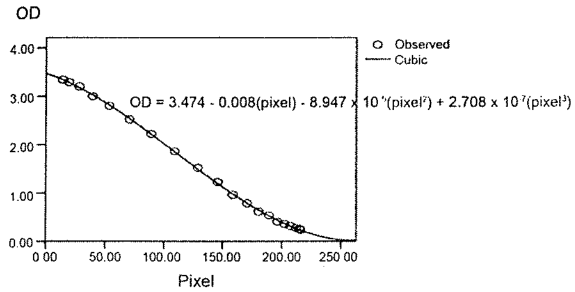

Fig. 3 The cubic curve estimation between optical density (OD) and pixel value

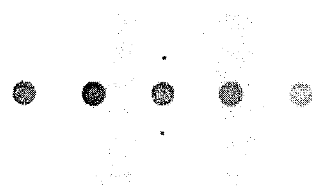

Fig. 4 Radiograph showing five holes image that result from grid alignment test. This radiograph shows a maximum optical density to the left of center. The result of this test is shown that grid is not properly aligned

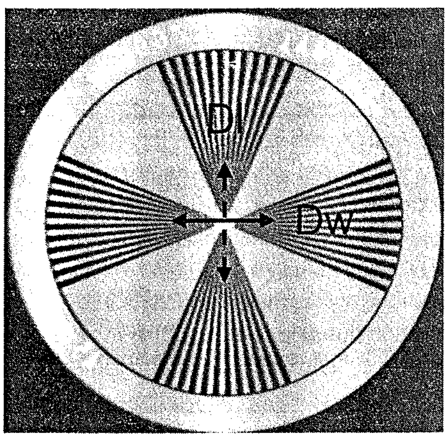

Fig. 5 Radiograph for finding the focal spot size by using star technique. The dark arrow shows the widest blur distance along cathode-anode direction (Dw), the dashed arrow shows blur distance along transverse direction (Dl)

spot size in the cathode-anode direction and Dl was calculated for finding focal spot size in the transverse direction. The authors determined equivalence limit of focal spot size that is calculated by both techniques which is ± 0.2 mm.

Statistical analysis

Equivalent test[11,13] was used to evaluate whether quality control in four elements of a general x-ray machine between using CR is sufficiently similar to a film method. By using 95% confidence interval (CI) of mean difference between both methods of each testing compared with equivalence limit of each testing. If 95% CI of mean difference between both methods is concluded equivalence limit ($\pm$ D), it will show that both methods are equivalent but if not, it will show that both methods are not equivalent as shown in Fig. 6.

Interobsever agreement of each testing was assessed by using Intra-class correlation (ICC) for continuous data [14-17]. Time consuming comparisons were performed by using paired t-test. A p-value of less than 0.05 was considered to indicate a statistically significant difference for time analyzed. All statistical analyses were performed by using SPSS version16.

Results

The results of four elements test for a general x-ray machine of both methods are shown in Table 1-Table 3. These results show that 95% confidence interval of different results of both methods are completely contained within equivalent limit. This means that quality control of four elements for a general x-ray machine of both methods is equivalent.

The ratio of radiation dose and time consuming that they were used in each checking element of both methods are shown in Table 4. The ratio of radiation dose between film and CR method in collimator alignment test and mAs reciprocity test were similar (the ratio was 1 times). The ratio of radiation dose between film and CR method in grid alignment test was 2.41 times. The highest ratio of radiation dose was large focal spot measurement (49.11 times). Additionally, time consuming of all checking elements by using CR method is less than film method with p-value < 0.001.

Interobserver agreement for all quality control measurements of both methods is shown in Table 5. There were almost perfect agreements for each element of quality control measurements.

The Second Part: Economic Evaluation

Materials and Method

Cost calculation

Economic evaluation was performed by using cost-minimization analysis to evaluate efficiency of

Table 1. Result of collimator alignment test of both methods (CR and film)

Observer	Equivalence limit (± Δ)	95%CI of difference size of width sides (CR-film)	95%CI of difference size of length sides (CR-film)	Result of equivalence test
1	± 0.2	-0.02, 0.03	-0.01, 0.04	Equivalence
2	± 0.2	0.01, 0.04	-0.04, -0.01	Equivalence

CR = computed radiography, CI = confidence interval

Table 2. Result of mAs reciprocity test and grid alignment test of both methods (CR and film)

Observer	Equivalence limit (± Δ)	mAs reciprocity test	Grid alignment test	Result of equivalence test
		95%CI of difference OD of both methods (CR-film)	95%CI of difference OD of both methods (CR-film)	
1	± 0.1	0.00, 0.01	-0.02, 0.02	Equivalence
2	± 0.1	0.00, 0.01	-0.02, 0.02	Equivalence

CR = computed radiography, CI = confidence interval

Table 3. Result of determination of focal spot sizes of both methods (CR and film)

Observer	Equivalence limit (± Δ)	Small focal spot sizes		Large focal spot sizes		Result of equivalence test
		95%CI of difference FS size of both method (CR-film)		95%CI of difference FS size of both method (CR-film)		
		Dw	Dl	Dw	Dl	
1	± 0.2	-0.02, -0.01	0.02, 0.04	-0.05, -0.03	0.00, 0.04	Equivalence
2	± 0.2	-0.01, 0.01	0.01, 0.04	-0.04, -0.02	-0.01, 0.03	Equivalence

CR = computed radiography, CI = confidence interval, FS = focal spot

Table 4. The ratio of radiation dose and time consuming that they were used in each element of one activity of each element of quality control testing for both methods

Type of quality control	Ratio of radiation dose/one activity	Time consuming (second)/one activity		
	Film method/CR method	Film method	CR method	p-value
Collimator alignment	1	1,081.19	1,040.60	<0.001
mAs reciprocity	1	1,101.23	833.25	<0.001
Grid alignment	2.41	833.37	747.08	<0.001
Focal spot (FS)				
Small FS	46.73	865.98	802.00	<0.001
Large FS	49.11	809.38	769.21	<0.001

CR = computed radiography

Table 5. Agreement between two observers for quality control measurement of both methods (film and CR)

Type of quality control	Film method	CR method
Collimator alignment	0.989 (0.984, 0.992)	0.966 (0.956, 0.974)
mAs reciprocity	1.000 (0.999, 1.000)	0.999 (0.999, 0.999)
Grid alignment	0.995 (0.994, 0.996)	0.997 (0.996, 0.998)
Focal spot (FS)		
Small FS	1.000 (1.000, 1.000)	0.985 (0.975, 0.991)
Large FS	1.000 (1.000, 1.000)	0.999 (0.999, 1.000)

CR = computed radiography, FS = focal spot
Number in parentheses was 95% confidence interval of agreement among two observers

both methods because outcomes of comparative result for quality control of the two alternatives in the first part are the same result for quality control. In applying the provider perspective, economic cost was used to evaluate the cost of quality control performance. The total cost of each element testing is comprised of direct cost and indirect cost. Direct cost is the cost of quality control activity of each element testing.

Direct cost in film method, labor costs were summed from the cost of physicist that perform those quality control. Material cost was summed up from the cost of films, paper sheath for film storage, chemical processing, water, electricity, maintenance and waste water treatment. Capital costs were calculated by using annual financial cost methods of cassette, automatic processors, automatic multi-loader, densitometer, warehouse to store films, areas of setting automatic processors and automatic multi-loader.

Regarding direct cost in the CR method, labor costs were summed up from the cost of the physicist that performed the quality control. Material cost was summed up from the cost of electricity and maintenance. Capital costs were calculated by using annual financial cost method of CR reader, imaging plate, computer for analysis, areas of setting CR reader and computer.

Indirect cost is the cost that is allocated by supportive units such as administration unit, personnel unit, logistic unit and finance unit. The total direct cost of supportive units was calculated from the labor costs, material costs and capital costs.

The total cost incurred by those supportive units was allocated to each element testing (collimator, mAs, grid and focal spot) by using a direct allocation method modified by appropriate allocation criteria such as number of personnel was allocation criteria of administration unit and personnel unit, material cost was allocation criteria of logistic unit and operating costs was allocation criteria of finance unit to those testing[18]. The unit cost of each element testing was then calculated by dividing the total cost by the number of each element testing that means dividing by 52 (sample size). All costs were expressed and analyzed in the currency of Thailand (baht) at the time of study (31.28 baht ≅ 1 US dollar).

Sensitivity analysis

The authors used the price of film that increases by 10 % every year to estimate the unit cost because of the price of the silver which is the component of the film increases about 10% per year[18] (2009 to 2013). Because of expected useful life of CR is eight years[20], cost of CR is not varied until it reached its useful life.

Results

Unit cost of labors, materials and capitals of each element quality control testing of both methods

Table 6 shows the unit costs of each element testing of film and CR methods. The unit costs of labor in each element testing by using film method were higher than using CR method. The highest unit costs of labor was in mAs reciprocity testing by using film method (58.66 baht), while the lowest was in grid alignment testing by using CR method (39.79 baht). The unit costs of material in each element testing by using film method were very high compared with the CR method. The unit cost of material in the focal spot measurement by using film was the highest (204.54 baht), compared with 6.28 baht by using CR. The unit costs of capital in each element testing by using film method were higher than those of the CR method.

The labor's unit cost ratio of film and CR method in each quality control testing was similar (249.90/223.32 = 1.12 times). The material's unit cost ratio among film and CR method was the highest in the focal spot measurement (204.54/6.28 = 32.57 times),

Table 6. Unit cost of labors, materials and capitals of each element of quality control testing for both methods

Type of quality control	Film method				CR method			
	Labor cost	Material cost	Capital cost	Unit cost of 1 activity	Labor cost	Material cost	Capital cost	Unit cost of 1 activity
Collimator alignment	57.60	30.52	18.69	106.81	55.43	6.27	10.80	72.51
mAs reciprocity	58.66	32.17	29.30	120.13	44.41	6.27	10.80	61.49
Grid alignment	44.39	30.90	21.11	96.40	39.79	6.27	10.80	56.87
Focal spot (FS)								
Small FS	46.14	204.54	15.07	265.75	42.72	6.27	10.80	59.80
Large FS	43.11	204.54	15.07	262.72	40.97	6.27	10.80	58.05
Total	249.90	502.67	99.24	851.81	223.32	31.40	54.00	308.72

CR = computed radiography, FS = focal spot

Table 7. Cost per one activity of each element of quality control testing for both methods

Type of quality control	Film method					CR method				
	Total DC	Total IDC	Total cost	No. of QC	Cost/1 activity	Total DC	Total IDC	Total cost	No. of QC	Cost/1 activity
Collimator alignment	5,174.15	380.09	5,554.24	52	106.81	3,573.59	196.90	3,770.49	52	72.51
mAs reciprocity	5,863.89	382.98	6,246.87	52	120.13	3,032.30	165.16	3,197.46	52	61.49
Grid alignment	4,672.72	340.08	5,012.80	52	96.40	2,807.04	150.25	2,957.29	52	56.87
Focal spot (FS)										
Small FS	12,582.92	1,236.04	13,818.96	52	265.75	2,950.55	159.00	3,105.55	52	59.80
Large FS	12,434.63	1,226.68	13,661.31	52	262.72	2,864.89	153.76	3,018.65	52	58.05
Total	40,728.31	3,565.87	44,294.18	52	851.81	15,228.37	825.07	16,053.44	52	308.72

CR = computed radiography, FS = focal spot, DC = direct cost, IDC = indirect cost, QC = quality control

while the collimator alignment testing (30.52/6.28 = 4.86 times) and the total ratio was 16 times (502.67/31.40).

Moreover, computed radiography is widely used in Thailand. So, quality control performance of the general x-ray machines by using CR method will save cost very much. From Table 6, the cost saving per one activity of four elements testing for a general x-ray machine was 543.09 (851.81-308.72) baht and 1,629.27 (3x543.09) baht per one year if frequency of four elements testing is three times per year. Now Phramongkutklao Hospital has ten general x-ray machines, so quality control performance of those general x-ray machines testing by using the CR method will save costs about 16,292.70 baht per year. In addition, the whole networking of Royal army hospitals have about 150 general x-ray machines. Therefore, Army medical department can save costs about 244,390.50 baht per year for four elements testing by using the CR method. Currently surveyed by department of medical science, there are about 8,000 general x-ray machines in Thailand. Therefore, performance of quality control for four elements testing by using the CR method will save costs about 13,034,160 baht per year.

Cost per one activity of each element quality control testing of both method

As shown in Table 7, the unit costs of each element testing by using film method are higher than using the CR method. The unit costs of four elements testing for film and CR methods were 851.81 baht and 308.72 baht, respectively.

Sensitivity analysis

When the price of film is increased by 10% each year over five years, the cost saving per one activity of four elements testing by using the CR

Table 8. Unit cost and cost savings of quality control testing for both methods per one general x-ray machines (adjusted with increasing price of film by forecasting five years later (year 2009 to 2013)

Year	Unit costof film method	Unit costof CR method	Cost savings per test	Annual cost savings per test*
2009	890.34	308.72	581.62	1,744.86
2010	932.71	308.72	623.99	1.871.97
2011	979.34	308.72	670.62	2,011.86
2012	1,030.03	308.72	721.31	2,163.93
2013	1,087.04	308.72	778.32	2,334.96

CR = computed radiography, QC = quality control
* Suppose frequency of four elements testing is three times per year

method instead of film method is shown in Table 8. By the year 2009, the cost saving will have increased from 1,744.86 baht in 2009 to 2,334.96 baht in 2013.

Discussion

The results of four elements test for a general x-ray machine of both methods indicate that performance of quality control for those testing by the CR method as equivalent to the film method.

Test performance time of each quality control by using the CR method is less than the film method (p-value < 0.001) because time in image processing and analysis by using CR method is less than the film method.

The ratio of radiation dose (film/CR) in grid alignment tests and focal spot measurement was significantly greater than 1 which means radiation dose using by the CR method is less than by the film method. This shows that performance of grid alignment tests reduces tube loading (by a factor of about 2.41) when compared with the film and CR method. Moreover, when comparing with the film and CR methods, reduction in tube loading for small and large focal spot measurements (by a factor of about 46.73 and 49.11, respectively).

There was almost perfect interobserver agreement for each element of quality control measurement between the two independent raters because of high reliability of the equipments that was calibrated before measurement.

In addition, the unit costs of each element testing by using the film method are higher than using the CR method. So, quality control performance of the general x-ray machines tested by using the CR method will save costs enormously. The main reason of cost reduction was high material cost that was used in the film method such as film, chemical processing, and paper sheath for film storage while those kinds of materials were not needed in the CR method. The highest unit cost of quality control was small and large focal spot measurement by using the film method (265.75 baht and 262.72 baht, respectively) were 4.44 and 4.53 fold higher than using the CR method. The high cost is due to the measurement of focal spot by the film method using special direct-film (PPL) that costs (171.20 baht/sheet) and is very high compared with screen-film (14.30 baht/sheet) that was used for the rest of element testing. Because the price of film is increasing every year, so quality control performance of the general x-ray machines testing by using CR will save cost more and more every passing year.

However, because of using the financial cost method for capital cost calculation, the cost difference might be higher if the authors were to use economic capital costing method[21]

Similar to a previous study, Rong XJ et al[22] measured focal spot size with slit camera method using CR and direct-exposed film. They found CR yield consistent results in measurements of x-ray tube focal spot sizes and significantly reduce time and tube loading requirements but they did not evaluate with cost.

These results are useful for quality control performance of the general x-ray machines in digital system by using the CR method. Now, the Army medical department has affiliated with 37 Royal army hospitals spread nationwide in which Phramongkutklao Hospital is the center of all hospitals. There is a project using telemedicine for exchanging patient's data between each other, giving advice in the diagnosis and treatment for the patients in military-based hospitals. It is simple and saves costs for technicians in military-based hospitals to perform quality checking of general x-ray machines and send quality control's digital image file by using telemedicine to the physicist at Phramongkutklao Hospital to analyze the quality of those machines and send the result to those hospitals and to give advice if those machines quality are improper.

However, the present study has some limitations. Firstly, although a general x-ray machine was randomly selected, but one machine might not be representatives of all x-ray machines. So, the authors will study other general x-ray machines by using these finding methods to generalize the result in the next study. Secondly, the unit costs of four elements of quality control testing for a general x-ray machine of both methods in this study were obtained from Phramongkutklao Hospital which might be different from others. Thus, if quality control performance by using the CR method were performed in other hospitals, such as private hospitals, the cost reduction of that quality control testing might yield different results.

Conclusion

Performance of quality control for collimator alignment tests, milliampere-sec (mAs) reciprocity test, grid alignment test and determination of focal spot size can be performed by the CR method instead of the film method. In addition, the unit cost, time consumed and radiation dose that were used in quality control of those tests using the CR method are less than those of the film method. Therefore, quality control performance of those elements testing by using the CR method is more efficient than the film method. The beneficial results from this project with the telemedicine system in the near future will contribute to all military-based hospitals.

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การประเมินทางเศรษฐศาสตร์ของการใช้เครื่องอ่านและแปลงสัญญาณภาพเอกซเรย์เป็นดิจิตอลเปรียบเทียบกับการใช้ฟิล์มในการควบคุมคุณภาพเครื่องเอกซเรย์ทั่วไป ณ โรงพยาบาลพระมงกุฎเกล้า

ศุภขจี แสงเรืองอ่อน, ทศพร วิมลเก็จ, มานัส มงคลสุข, สมรัตน์ เลิศมหาฤทธิ์, เยาวนา ธนะพัฒน์, บุษบง หนูหล้า, กมลวรรณ ธังศิริ, ภิรมย์ กมลรัตนกุล

วัตถุประสงค์: *เพื่อประเมินประสิทธิภาพของการควบคุมคุณภาพเครื่องเอกซเรย์ทั่วไประหว่างการใช้เครื่องอ่านและแปลงสัญญาณภาพเอกซเรย์เป็นดิจิตอลและวิธีฟิล์ม*

วัสดุและวิธีการ: *ทำการศึกษาการใช้เครื่องอ่านและแปลงสัญญาณภาพเอกซเรย์เป็นดิจิตอลในการควบคุมคุณภาพเครื่องเอกซเรย์ทั่วไปโดยเปรียบเทียบกับวิธีฟิล์มซึ่งเป็นวิธีมาตรฐาน โดยใช้ผู้วัด 2 คนที่เป็นอิสระต่อกันในการวิเคราะห์ผลของการควบคุมคุณภาพของทั้ง 2 วิธี การประเมินผลทางเศรษฐศาสตร์กระทำโดยใช้การวิเคราะห์ต้นทุนที่ต่ำสุด ข้อมูลทั้งหมด (การควบคุมคุณภาพ, ต้นทุน) รวบรวมจากโรงพยาบาลพระมงกุฎเกล้าระหว่างเดือนสิงหาคม พ.ศ. 2550 ถึงเดือนมกราคม พ.ศ. 2551*

ผลการศึกษา: *ผลของการควบคุมคุณภาพเครื่องเอกซเรย์ทั่วไปโดยการใช้เครื่องอ่านและแปลงสัญญาณภาพเอกซเรย์เป็นดิจิตอล และวิธีฟิล์มมีความเทียบเคียงกัน ความสอดคล้องของผู้วิเคราะห์ผลทั้ง 2 คน อยู่ในระดับเกือบสมบูรณ์ โดยต้นทุนต่อการควบคุมคุณภาพ 1 ครั้ง, เวลาและปริมาณรังสีที่ใช้สำหรับเครื่องอ่านและแปลงสัญญาณภาพเอกซเรย์เป็นดิจิตอลในการควบคุมคุณภาพเครื่องเอกซเรย์ทั่วไปน้อยกว่าวิธีฟิล์ม (p-value < 0.001)*

สรุป: *การควบคุมคุณภาพเครื่องเอกซเรย์ทั่วไปโดยใช้เครื่องอ่านและแปลงสัญญาณภาพเอกซเรย์เป็นดิจิตอลมีประสิทธิภาพมากกว่าวิธีฟิล์ม การใช้เครื่องอ่านและแปลงสัญญาณภาพเอกซเรย์เป็นดิจิตอลสำหรับการควบคุมคุณภาพเครื่องเอกซเรย์ทั่วไปจะทำให้ประหยัดต้นทุนเป็นอย่างมาก*
