◈ Original Article ◈

Investigation About Quality Control of General X-ray System

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Abstract

This test is for checking investigation about quality control of general X-ray system in clinic and hospital. We compared general X-ray system of clinic and hospital which are selected freely in the metropolitan area using PMX-III and carried out quality control. Carried out Kilovoltage test, mR/mAs output test, Light filed/Beam alignment test, Half value layer test. Most of test result are appeared that failure rates of clinic is higher than hospital one. Therefore, we should lower failure rates through regular quality control and make environment which can get high quality image.

Key word : General X-ray system, PMX-III, Kilovoltage test, mR/mAs output test, Light filed/Beam alignment test

Ⅰ. Introduction

It is inevitable to use radiation therapy for medical treatment and its use has increased and expanded : Therefore, proper usage and quality control can result the best treatment. It is already known that inappropriate picture quality X-ray for imaging diagnosis may cause unnecessary irradiation of radioactive rays to a patient, which results in excessive medical expenses. Usually, the main cause of inappropriate picture quality for imaging diagnosis is low quality of diagnosis X-ray device. An analysis shows that this causes a retake. Therefore, it is necessary to maintain quality in a proper and reasonable manner based on the scale of diagnostic radiographic facilities in order to reduce such effects. However, since radiation operators who are actually using such devices can set conditions based on their experiences and can readjust after taking an image as PACS(Picture Archiving Communication System) has been introduced, quality control become less important. Therefore, we conducted a quality check to find out the status of quality control of diagnostic radiographic devices at clinic and hospital.[1~2]

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Ⅱ. Material & Method

1. Object of Study

We conducted tube voltage test, mAs test, error test of X-ray incidence volume and irradiation volume, exposure reproducibility test and half value thickness test among non-invasive tests on the radiographic equipment at the clinic and hospital in urban areas.

2. Examination Method

1) kVp Test

(1) Purpose

Voltage neighboring a X-ray tube determines X-ray volume as well as the energy generated in the X-ray tube. The purpose is to maintain contrast and photographic density of X-ray images consistently by maintaining kVp accurately and to reduce its exposure dose to patients.

(2) Test Method

① Preheat a tube and PMX-III before test.

② Place PMX-III on the imaging stand.

③ Set SID(Source Image Distance) as 100 cm and match the center line to the measuring section of PMX-III, and then collimate.

④ Change measuring ranges to 80, 100 and 120 kVp and measure 5times at each kVp(Fix at 200 mA, 0.1 sec).

⑤ Record the measured values and check any abnormality.

⑥ Use the following Equation 1 to check abnormality.

$$PAE = \frac{Xp - \overline{X}}{Xp} \times 100(\%) \qquad (1)$$

PAE (Percent Average Error)

Xp : Set value

$\overline{X}$: Average of the set value

(3) Allowable Error

PAE of tube voltage should be within ±10% of the set value.

2) mAs Test

(1) Purpose

It is designed to check if the same exposure always takes place by using mAs and kVp regardless of dose duration and mA combination.

(2) Test Method

① Place a lead gown on the imaging stand(A lead gown reduces back scattering).

② Conduct the same procedure as ①, ② and ③ of tube voltage test.

③ Measure under the following conditions

· 80 kVp, 1/10 sec, 100 mA

· 80 kVp, 1/20 sec, 200 mA

· 80 kVp, 1/30 sec, 300 mA

· 80 kVp, 1/40 sec, 400 mA

④ Calculate mR/mAs ratio and record the result.

⑤ Calculate changes of reproducibility(Eq. 2).

$$PRV = \frac{\frac{(MAXmR/mAs - MINmR/mAs)}{2}}{AveragemR/mAs} \qquad (2)$$

(3) Allowable Error

Reproducibility of mAs must be within ± 15%.

3) Light Filed/Beam Alignment Test

(1) Purpose

It is designed as accuracy of light filed and beam alignment reduces unnecessary exposure dose and improves contrast of images.

(2) Test Method

① Fix SID as 100 cm and place a X-ray tube vertically on the imaging stand.

② Place a collimator template on the imaging stand and match the hole to the right shoulder of a patient.

③ Adjust beam alignment to match the rectangular exterior line of the template.

④ Place the beam alignment test tool in the center of collimator template.

⑤ Irradiate in the hand exposure conditions.

⑥ Measure images after taking images and record the results.

(3) Allowable Error

Surrounding error of beam alignment and light filed must be within ± 2% of SID.

4) Reproducibility of Exposure Dose

(1) Purpose

Its purpose is to assess quality and reliability of medical radiographic diagnostic devices. The measured value should be the same at every measurement when kVp, mAs, dose duration and imaging distance are set the same. It closely involves with the fact that picture density is the same at each imaging.

(2) Test Method

① Conduct the same procedure as ①, ② of mA test method.

② Fix at 80 kVp, 100 mA and change dose duration to 0.5, 1.0 and 2.0 sec. Irradiate 3 times respectively and record the results.

③ Fix at 100 kVp, 200 mA and change dose duration to 0.5, 1.0 and 2.0 sec. Irradiate 3 times respectively and record the results.

④ CV (Calculate co-efficiency of Variation) using the results of the above ② and ③(Eq. 3).

$$CV = \frac{SD}{\overline{X}} \tag{3}$$

(3) Allowable Error

CV for the exposure dose of diagnostic radiation generating devices must be less than 0.05.

5) Half Value Thickness Test

(1) Purpose

When X-rays are generated : They come from a tube as a number of energy beams and consist of various pulses and frequencies, and soft lines and hard lines. Soft lines have low energy and are absorbed in to soft tissues, thus, increase exposure dose to a patient. It is designed to check the tube settings to keep a proper level of exposure of a patient to a minimum by using filters.

(2) Test Method

① Place a lead gown on the imaging stand.

② Place PMX-Ⅲ, half value thickness test equipment and an X-ray tube.

③ Fix the condition at 80 kVp, 100 mA, 0.1 sec.

④ Record the results of 2 times which decreases thickness of filters, opposite from thickness X-ray filters.

⑤ Calculate the average of the above recorded and then generate the half value thickness by drawing an attenuated curve.

(3) Permissible Range

At 80 kVp, half value thickness must be more than equivalent to 2.3 mmAl.

Ⅲ. Result

1. kVp Test

As a result of kVp test, all clinic and hospital show normal results at 80 kVp, 30% of clinic and 8% of hospital show abnormality at 100 kVp and 60% of clinic and 58% of hospital show abnormality at 120 kVp(Table 1, 2).

2. mAs Test

As a result of mAs test, while all hospital show normality, 60% of clinic show abnormality(Table 3).

Table 1. Clinic of kilovoltage test

No.	kVp	PAE(%)	kVp	PAE(%)	kVp	PAE(%)
1	80	−4.80	100	13.7	120	26.8
2		−2.02		2.44		3.63
3		−		14.9		17.6
4		0.00		3.60		20.3
5		3.25		4.40		7.03
6		3.93		17.9		22.5
7		−1.30		1.06		1.88
8		0.83		2.94		12.1
9		2.33		6.38		−
10		2.62		3.72		6.93

Table 2. Hospital of kilovoltage test

No.	kVp	PAE(%)	kVp	PAE(%)	kVp	PAE(%)
1	80	−3.06	100	13	120	17
2		3.4		3.36		3.85
3		1		−0.54		−0.65
4		−2.85		1.02		0.42
5		−0.38		−0.43		−0.50
6		−0.63		−0.93		−0.92
7		−3.25		−3.77		−
8		−4.58		−5.5		−
9		−0.46		−0.27		−
10		−0.29		−2.67		−
11		−5.54		−5.77		−
12		−1.33		−1.27		−

Table 3. Clinic & hospital of mR/mAs output test

No.	Clinic PRV(%)	Hospital PRV(%)
1	8.02	8.35
2	4.02	2.91
3	20.4	2.69
4	18.0	3.16
5	28.6	2.33
6	9.86	9.27
7	22.2	0.75
8	19.5	0.14
9	5.50	0.60
10	33.5	0.57
11	×	0.97
12	×	0.64

Table 4. Clinic of light filed/beam alignment(unit : %)

No.	Left/Right Error	Upper/Lower Error
1	0.60	1.00
2	1.90	0.90
3	1.70	1.70
4	1.00	1.50
5	0.20	0.80
6	1.10	1.40
7	1.50	1.50
8	1.00	2.00
9	1.25	1.50
10	0.50	0.25

Table 5. Hospital of light filed/beam alignment(unit : %)

No.	Left/Right Error	Upper/Lower Error
1	1.30	0.60
2	1.00	0.60
3	0.50	0.25
4	0.75	2.00
5	0.20	1.00
6	0.50	0.40
7	0.50	0.10
8	1.00	0.50
9	0.10	0.20
10	0.40	0.10
11	0.00	2.00
12	1.80	1.50

3. Light filed/Beam alignment test

As a result of difference test of X-ray beam alignment and beam alignment, 10% of clinic and 17% of hospital show abnormality(Table 4, 5).

4. Reproducibility of exposure dose test

As a result of reproducibility of exposure dose test, all hospital show normality while clinic show the more problems when exposure dose duration is the shorter(Table 6, 7).

5. Half Value Thickness Test

As a result of half value thickness test, all the medical institutions show normal values(Table 8).

Table 6. Clinic of exposuer repeatability

No.	kVp	mA	sec	CV	kVp	mA	sec	CV
			0.5	0.049			0.5	0.080
1			1.0	0.034			1.0	0.068
			2.0	0.022			2.0	0.047
			0.5	0.072			0.5	0.003
2			1.0	0.009			1.0	0.006
			2.0	0.000			2.0	0.003
			0.5	0.054			0.5	0.017
3			1.0	0.036			1.0	0.068
			2.0	0.044			2.0	0.320
			0.5	0.093			0.5	0.106
4			1.0	0.080			1.0	0.047
			2.0	0.049			2.0	0.061
			0.5	0.049			0.5	0.061
5			1.0	0.034			1.0	0.076
	80	100	2.0	0.019	100	200	2.0	0.075
			0.5	0.066			0.5	0.145
6			1.0	0.049			1.0	0.106
			2.0	0.051			2.0	0.037
			0.5	0.087			0.5	0.080
7			1.0	0.039			1.0	0.028
			2.0	0.037			2.0	0.031
			0.5	0.047			0.5	0.026
8			1.0	0.011			1.0	0.158
			2.0	0.007			2.0	0.019
			0.5	0.193			0.5	0.022
9			1.0	1.240			1.0	0.062
			2.0	0.022			2.0	0.057
			0.5	0.010			0.5	0.012
10			1.0	0.002			1.0	0.005
			2.0	0.001			2.0	0.010

Table 7. Hospital of exposuer repeatability

No.	kVp	mA	sec	CV	kVp	mA	sec	CV
1	80	100	0.5	0.026	100	200	0.5	0.005
			1.0	0.011			1.0	0.001
			2.0	0.006			2.0	0.021
2			0.5	0.004			0.5	0.002
			1.0	0.002			1.0	0.001
			2.0	0.002			2.0	0.001
3			0.5	0.003			0.5	0.004
			1.0	0.001			1.0	0.004
			2.0	0.001			2.0	0.001
4			0.5	0.002			0.5	0.001
			1.0	0.001			1.0	0.001
			2.0	0.001			2.0	0.001
5			0.5	0.000			0.5	0.002
			1.0	0.000			1.0	0.000
			2.0	0.000			2.0	0.000
6			0.5	0.001			0.5	0.001
			1.0	0.003			1.0	0.001
			2.0	0.001			2.0	0.000
7			0.5	0.012			0.5	0.009
			1.0	0.071			1.0	0.009
			2.0	0.007			2.0	0.015
8			0.5	0.011			0.5	0.003
			1.0	0.022			1.0	0.002
			2.0	0.000			2.0	0.001
9			0.5	0.012			0.5	0.006
			1.0	0.025			1.0	0.008
			2.0	0.008			2.0	0.013
10			0.5	0.024			0.5	0.003
			1.0	0.024			1.0	0.003
			2.0	0.004			2.0	0.003
11			0.5	0.012			0.5	0.003
			1.0	0.000			1.0	0.003
			2.0	0.012			2.0	0.012
12			0.5	0.001			0.5	0.003
			1.0	0.020			1.0	0.019
			2.0	0.017			2.0	0.001

Table 8. Clinic & Hospital half value layer test (unit : ㎜Al)

No.	Clinic	Hospital
1	2.95	3.65
2	3.25	4.14
3	2.93	2.98
4	2.90	5.00
5	3.45	3.87
6	3.18	3.96
7	3.75	4.01
8	3.60	3.21
9	3.20	3.54
10	3.65	3.81
11	×	3.60
12	×	3.24

Ⅳ. Discussion

Test results show there are differences depending on medical institutions. However, in the tube voltage test, the higher is the tube voltage, the more errors show the both institutions.[3~6] This can cause more serious problems because radiation operators may readjust the taken images by using PACS or changing conditions based on their own experiences in order to obtain necessary images which are appropriate for imaging diagnosis.[7~10] This may increase unnecessary radioactive exposure to patients. In the mAs test, a significantly larger number of clinic show failure than hospital. It is because of deterioration and lack of regularly quality control. In the difference test of beam alignment and light filed in clinic is slighter than that in hospital. This causes irradiation towards the not designated areas : Therefore, it increases unnecessary dose to a patient and can result in incorrect imaging diagnosis. In the reproducibility of exposure dose test, all hospital show normality while clinic show serious problems.[11] This may increase unnecessary radiological exposure and medical costs as it may require a retake due to unstable X-ray image density at each imaging. The entire clinic and hospital show a normal half value thickness. It indicates that there is little unnecessary dose to a patient due to soft lines. As shown in a foreign research(Table 9), the quality deterioration of equipment is an important factor of inappropriate picture quality for imaging diagnosis.

This Table 10 was HVL according to permissible range where were IEC(International Electronical Commission) and Korea. The result of HVL test indicated that was showed normal figure at IEC and Korea regulation.[12]

Table 9. Reasearch report

Research report	Failure rete	Main cause
Blue Shield	50%	Fault of radiologist's skill, Declining performance of equipment
Du Pont	13%	Declining performance of equipment
Berry & Oliver	5.3%	Exposure condition fail, Mechanical trouble
Micknley & McCauley	8.9%	Exposure condition fail, Mechanical trouble, Badness of maintanance and management

Table 10. IEC 60601-2-40(2000-01) Particular requirements for the safety of X-ray equipments(unit : mmAl)

kVp	IEC	Korea
50	1.8	–
60	2.2	1.3
70	2.5	–
80	2.9	2.3
90	3.2	–
100	3.8	–
110	3.9	–
120	4.3	–

Ⅴ. Conclusion

In the modern medical field, diagnostic radiation generating devices are necessary tolls. Therefore, it is neccessary to establish an environment where patients can be high quality of imaging by regularly checking the quality and considerung ALARA(As Low As Reasonably Achievable) rules based on otimized radioactive exposure.

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