ENTRANCE SURFACE DOSE AND IMAGE QUALITY: COMPARISON OF ADULT CHEST AND ABDOMINAL X-RAY EXAMINATIONS IN GENERAL PRACTITIONER CLINICS, PUBLIC AND PRIVATE HOSPITALS IN MALAYSIA

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Received June 2 2008, revised December 23 2008, accepted January 18 2009

This study was undertaken to compare the entrance surface dose (ESD) and image quality of adult chest and abdominal X-ray examinations conducted at general practitioner (GP) clinics, and public and private hospitals in Malaysia. The surveyed facilities were randomly selected within a given category (28 GP clinics, 20 public hospitals and 15 private hospitals). Only departmental X-ray units were involved in the survey. Chest examinations were done at all facilities, while only hospitals performed abdominal examinations. This study used the x-ray attenuation phantoms and protocols developed for the *Nationwide Evaluation of X-ray Trends (NEXT)* survey program in the United States. The ESD was calculated from measurements of exposure and clinical geometry. An image quality test tool was used to evaluate the low-contrast detectability and high-contrast detail performance under typical clinical conditions. The median ESD value for the adult chest X-ray examination was the highest (0.25 mGy) at GP clinics, followed by private hospitals (0.22 mGy) and public hospitals (0.17 mGy). The median ESD for the adult abdominal X-ray examination at public hospitals (3.35 mGy) was higher than that for private hospitals (2.81 mGy). Results of image quality assessment for the chest X-ray examination show that all facility types have a similar median spatial resolution and low-contrast detectability. For the abdominal X-ray examination, public hospitals have a similar median spatial resolution but larger low-contrast detectability compared with private hospitals. The results of this survey clearly show that there is room for further improvement in performing chest and abdominal X-ray examinations in Malaysia.

INTRODUCTION

While the medical benefits from an X-ray examination outweigh the risk to the individual, medical practitioners have the obligation to keep exposures as low as reasonably achievable. Reference doses or guidance levels have been recommended by various organisations as a means of patient dose reduction^(1,2). Patient dose measurement and image quality assessment are important in the optimisation of protection in medical usage of ionising radiation. Optimisation involves the assessment of detriment associated with radiation exposure and an estimation of the benefit derived from the procedure with optimal image quality. Over the past decade, substantial reductions in radiation doses to patients with minimal effect on diagnostic image quality have been achieved in many parts of the developed countries^(3–6).

In the medical application of ionising radiation, one should have knowledge of the magnitude of the radiation dose associated with the procedures in order to evaluate the potential benefit–risk ratio. There are a number of ways in which radiation exposure and dose in medicine can be evaluated. Measured quantities include air kerma, entrance surface dose (ESD), dose–area product, dose–length product and administered activity⁽⁷⁾. However, the quantity that is generally of greatest interest in routine measurements of the patient dose in diagnostic radiology is the ESD. It is expressed as a dose to air, since air will yield a dose estimate that is intermediate between a number of other suggested reference tissues across the diagnostic energy range.

Malaysia is a healthcare level II country (based on a physician's density of 1000–3000 persons per physician)⁽⁸⁾ according to the definition by the United Nations Scientific Committee on the Effects of Atomic Radiation. Over the years, various steps have been taken to enhance the safety and quality

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of radiology services that include certification of X-ray equipment and associated facilities, implementation of quality assurance (QA) programmes and training of personnel working in radiology services.

In 2001, there were 680 general practitioner (GP) clinics, 132 public and 97 private hospitals in Malaysia. Chest radiography is the most frequently performed X-ray examination in most of the radiology departments and accounts for 63% of all radiographic examinations performed in the country⁽⁸⁾. Under the Malaysian public health policy, the abdominal X-ray examination is allowed only in the public and private hospitals served by radiologists. Radiographic examinations of the abdomen and pelvis account for ~8% of all X-ray examinations performed in the country⁽⁹⁾.

The objective of this study was to compare the ESD and the image quality of adult chest and abdominal X-ray examinations for GP clinics, public and private hospitals in Malaysia. Such a comparison can contribute to the development of effective methods for patient dose reduction, while maintaining optimal clinical benefit. It may also serve to add demographic information to issues regarding reference levels and worldwide use of imaging equipment in level II countries.

MATERIALS AND METHODS

Sample selection

The survey sample consisted of randomly selected medical facilities within a given category (28 GP clinics, 20 public hospitals and 15 private hospitals). Only departmental X-ray units were involved in this survey. All facilities in the sample were surveyed for the chest X-ray examination while only hospitals were surveyed for the abdomen examination. Typical characteristics of the X-ray equipment surveyed are given in Table 1. Each X-ray system undergoes an extensive QA procedure following the recommendations of the Institute of Physics and Engineering in Medicine (IPEM)⁽¹⁰⁾. Twenty-seven centres were using a screen–film combination of speed class 400 or faster, 31 centres that of speed class of less than 400 and 5 centres those of unknown speed. Table 1 shows that a majority of the GP clinics and private hospitals still use single-phase equipment and perform the examination using a manually selected technique.

Radiographic nationwide evaluation of X-ray trends phantoms

In the United States, the Conference of Radiation Control Program Directors (CRCPD), state radiation

Table 1. Characteristics of equipment surveyed in this study.

Parameters		Number of sites (<i>n</i>)						
		Chest X-ray				Abdominal X-ray		
		All ^a	GPs ^b	Public ^c	Private ^d	All ^a	Public ^c	Private ^d
Number of centres		63	28	20	15	35	20	15
Types of generators	Single phase	27	24	1	2	3	1	2
	Three phase	25	1	12	12	24	12	12
	High frequency	3	3	0	0	0	0	0
	Constant potential	8	0	7	1	8	7	1
Types of systems	Film–screen	61	28	18	15	33	18	15
	Computed radiography	2	0	2	0	2	2	0
Screen–film speed class	≥400	27	2	18	7	25	18	7
	<400	31	23	1	7	8	1	7
	Others	5	5	0	0	2	0	2
Types of processors	Manual	9	9	0	0	0	0	0
	Automatic	44	19	13	12	25	13	13
	Daylight	8	0	6	2	8	6	2
	Digital	2	0	2	0	2	2	0
No. of sites using grids		16	3	8	5	32	19	13
No. of sites using AEC		3	0	3	0	8	5	3
Mean weekly workload (examinations per week)		142	22	287	172	32	37	27

Note: GP clinics do not perform the abdominal examination.

^aAll centres.

^bGPs clinics.

^cPublic hospitals.

^dPrivate hospitals.

health programmes and the US Food and Drug Administration Center for Devices and Radiological Health (CDRH) collaborate to document trends in diagnostic X-ray practice through the Nationwide Evaluation of X-ray Trends (NEXT) programme. Since the 1970s, the NEXT programme has characterised the radiation doses that patients receive during selected diagnostic X-ray examinations. NEXT protocols provide survey procedures for capturing technical data associated with the practice of the diagnostic X-ray procedure, including the ESD, image quality, clinical technique factors, quality of film processing and general quality control (QC) procedures^(11,12).

Adult chest phantom

The NEXT radiographic chest phantom^(11,13) was used to measure exposures under typical clinical conditions for the adult posteroanterior chest X-ray projection. Beam quality was determined using the clinical kVp technique, and radiographs of the phantom were processed using the film processor typically used for processing clinical films.

An image quality test tool⁽¹²⁾ with two sets of test objects was used to evaluate both low-contrast detectability (hole patterns) and high-contrast spatial resolution (mesh patterns) (Figure 1). The tool was positioned in the X-ray beam with the NEXT phantom and then radiographed (Figure 2a). Four exposures were made, of which one phantom image was retained for image quality evaluation.

Adult abdomen phantom

The NEXT adult abdomen phantom was used to measure X-ray exposures under typical clinical conditions for the anteroposterior abdomen projection. The phantom approximates the X-ray attenuation properties of an average-size adult (~74 kg and 23 cm diameter abdomen)^(12,14) was used to measure exposures under typical clinical conditions for the anteroposterior abdomen X-ray projection. Beam quality was determined using the clinical kVp technique. The phantom, X-ray equipment and image quality test tool (Figure 1) for abdominal exposures were arranged as in Figure 2b. Four exposures were made, of which one phantom image was retained for image quality assessment. Radiographs of the phantom were processed using the film processor typically used for processing clinical films.

Survey procedures

NEXT protocols

The survey was carried out following the NEXT protocols for the survey of adult chest radiography⁽¹¹⁾ and adult abdomen radiography⁽¹²⁾.

Figure 1. Schematic diagram of image quality test tool shows the specification of the holes and copper mesh patterns⁽¹⁴⁾. The holes are 8 mm in diameter, and the mesh patterns are 1.5 cm × 1.5 cm. Values inside the squares indicate the mesh count. The holes are bored to the indicated depth in a 6.1-mm thick aluminium disc.

Technique factors (kV and mA) and source–image distance (SID) were recorded for each system. X-ray beam quality was measured according to the IPQM protocol⁽¹⁰⁾.

Measurement of ESD

X-ray exposure was measured using a 6 cc ionisation chamber (Model 20X6-6, Radcal, Monrovia, California, USA) connected to an electrometer (Model 2026C Radcal). The measurements were made with the phantom using the beam geometry and clinical technique factors for routine chest and abdomen X-ray examinations, respectively. The ESD was then calculated using an inverse-square correction from the position of the ionisation chamber to the entrance surface of the standard patient.

Assessment of image quality

An image of the phantom with the image quality test tool was obtained for each system. Images were assessed for indicators of image quality, namely the film background optical density (OD), low-contrast detectability (number of visible holes) and spatial resolution (number of visible meshes) using the dedicated viewbox at the surveyed facilities. The film was masked and the neighbouring viewboxes were turned off to reduce ambient light from

Figure 2. Phantom and X-ray equipment set-up for X-ray exposure measurements: (a) posteroanterior (P/A) chest and (b) anteroposterior (A/P) abdomen.

the environment. The film OD was measured using a densitometer model RMI 2332 (X-RITE, Inc.).

RESULTS

Sample selection

The characteristics of the X-ray machines and film processing can be seen to vary with types of examinations and between types of facility (Table 1). GP clinics conduct the surveyed X-ray examinations

without using automatic exposure control (AEC). Anti-scatter grids are used more frequently during abdominal examinations than for chest examinations, with GP clinics showing the lowest rate of grid use.

For the chest examination (Table 2), public hospitals have the highest median kV values (median: 90.0 kV) compared with GP clinics (median: 80.0 kV) and private hospitals (median: 80.0 kV). The median value of mAs is the highest for GP clinics (9.8 mAs) when compared with public

Table 2. Statistical summary of exposure techniques for chest X-ray examinations performed at surveyed facilities.

Parameters	kVp				mAs				HVL (mm Al)			
	All ^a (n= 63)	GPs ^b (n= 28)	Public ^c (n= 20)	Private ^d (n= 15)	All ^a (n= 63)	GPs ^b (n= 28)	Public ^c (n= 20)	Private ^d (n= 15)	All ^a (n= 68)	GPs ^b (n= 28)	Public ^c (n= 20)	Private ^d (n= 15)
Mean	86.4	82.6	91.3	86.9	7.8	10.3	5.2	6.5	3.0	2.7	3.1	3.1
Minimum	60.0	60.0	70.0	64.0	1.2	3.0	1.2	1.4	1.8	1.8	2.1	2.1
Maximum	125.0	120.0	125.0	125.0	25.6	25.6	10.0	25.6	4.7	4.7	4.7	4.7
Median	80.0	80.0	90.0	80.0	6.0	9.8	5.5	5.0	2.7	2.6	2.9	2.7
First quartile	75.0	74.8	73.8	75.0	4.0	6.0	3.8	2.8	2.5	2.5	2.5	2.5
Third quartile	91.0	84.0	100.0	96.0	10.0	12.0	6.6	5.5	3.4	2.9	3.7	3.5
Standard deviation	17.2	13.9	19.6	18.6	5.7	6.2	2.2	6.5	0.8	0.6	0.9	0.8

^aAll centres.^bGPs clinics.^cPublic hospitals.^dPrivate hospitals.

(median: 5.5 mAs) and private (median: 5.0) hospitals. Both GP clinics and private hospitals have comparable median beam quality (2.9 mm and 2.7 mm Al, respectively). For abdominal examinations (Table 3), public hospitals have a lower median kV value (median: 67 kV) compared with private hospitals (median: 70 kV). Both hospital types have the same median mAs (median: 50 mAs). Beam quality was comparable between public hospitals (median: 2.56 mm Al) and private hospitals (median: 2.51 mm Al). All systems were configured at an SID >120 cm for chest examinations and >100 cm for abdominal examinations.

Measurement of ESD

Adult chest examination

The median ESD for the GP clinics was the highest (0.25 mGy), followed by private (0.22 mGy) and public (0.17 mGy) hospitals. The median ESD for all facilities is 0.19 mGy. The variation of ESD (Figure 3) for GP clinics is wider than that for private and public hospitals. A possible explanation could be the differences in the tube potential, beam quality and mAs values used (Table 2); however, the fact that a significant number of GP sites manually process their films (Table 1) is also likely to be a contributor to the broad variability in the ESD for GP clinics.

Adult abdominal examination

The median ESD for adult abdominal X-ray examinations in public hospitals (3.35 mGy) is higher than that for private hospitals (2.81 mGy). The median ESD for all facilities is 3.07 mGy. Private hospitals have a larger variation of ESD (Figure 4). A possible explanation could be the differences in the tube potential and mAs used (Table 3). Table 1 also documents that private hospitals use a range of film combination speeds, which can also contribute to the broader range of ESD values observed.

Image quality

Results of image quality assessment show that, for the chest X-ray examination, all facility types have a similar median for spatial resolution and low-contrast detectability (Table 4). The median film OD (Table 5) for private hospitals (1.80) is the highest followed by those for public hospitals (1.57) and GP clinics (1.49). The median film OD was 1.60 for all facilities.

For the abdominal X-ray examination, public hospitals have similar median values for spatial resolution and better low-contrast detectability compared with private hospitals (Table 4). Private hospitals

Table 3. Statistical summary of exposure techniques for abdominal X-ray examinations performed at surveyed facilities.

Parameters	kVp			mAs			HVL (mmAl)		
	All ^a (n = 35)	Public ^b (n = 20)	Private ^c (n = 15)	All ^a (n = 35)	Public ^b (n = 20)	Private ^c (n = 15)	All ^a (n = 35)	Public ^b (n = 20)	Private ^c (n = 15)
Mean	68.9	68.5	69.5	50.3	46.3	55.7	2.7	2.68	2.70
Minimum	60.0	60.0	60.0	18.7	18.7	20.0	2.1	2.06	2.08
Maximum	80.0	77.0	80.0	96.0	65.0	96.0	3.9	3.95	3.97
Median	70.0	67.0	70.0	50.0	50.0	50.0	2.5	2.56	2.51
First quartile	65.5	65.8	65.5	35.0	32.0	47.5	2.3	2.31	2.28
Third quartile	73.0	73.0	72.5	64.0	61.0	64.5	2.9	2.92	2.71
Standard deviation	5.0	4.9	5.2	17.3	15.5	18.6	0.6	0.53	0.64

Note: GP clinics do not perform the abdominal examination.

^aAll centres.

^bPublic hospitals.

^cPrivate hospitals.

Figure 3. Box-whisker plot of ESD for adult chest X-ray examinations performed at indicated facility types. Upper and lower edges of the box are 25th and 75th percentiles, respectively. Whiskers extend to the range outliers excluded. The median is marked in the box. The median, which is not central, represents the study population, which is not normally distributed.

have slightly higher median film OD (1.67) compared with public hospitals (1.62). The median film OD was 1.64 for all hospitals. It is well understood that film OD, screen-film combination speed and radiographic technique, all affect the ultimate image quality; therefore, the observed variability of all these factors among public and private hospitals makes it difficult to isolate one factor as the reason for the observed differences in image quality.

Figure 4. Box-whisker plot of ESD for the adult abdominal X-ray examinations performed at the indicated facility types. Upper and lower edges of the box are 25th and 75th percentiles, respectively. Whiskers extend to the range outliers excluded. The median is marked in the box. The median, which is not central, represents the study population, which is not normally distributed.

DISCUSSION

To the authors' knowledge, this is the first such study to report on the use of the NEXT protocols for the measurement of the ESD and image quality of chest and abdominal radiography for a level II country. The authors found that the use of the NEXT patient-equivalent phantoms in conjunction with their respective protocols provides a more practical and simpler approach for measuring the ESD and image quality of adult chest and abdominal X-ray examinations. Intercomparison between doses delivered by the same systems at different times,

Table 4. Summary of image quality evaluation for chest and abdominal examinations.

Parameters	Examination											
	Chest						Abdomen					
	Number of image quality meshes visible			Number of image quality holes visible			Number of image quality meshes visible			Number of image quality holes visible		
	Mean	Median	Range (minimum, maximum)	Mean	Median	Range (minimum, maximum)	Mean	Median	Range (minimum, maximum)	Mean	Median	Range (minimum, maximum)
Public hospital Private hospital GP clinic All	5.2	5.0	(4.0, 6.0)	5.8	5.0	(4.0, 6.0)	4.5	5.0	(3.0, 6.0)	4.8	4.5	(3.0, 7.0)
	5.3	5.0	(4.0, 6.0)	4.8	5.0	(4.0, 6.0)	4.5	5.0	(3.0, 5.0)	4.6	5.0	(3.0, 6.0)
	5.0	5.0	(3.0, 6.0)	4.7	5.0	(3.0, 6.0)	N/A	N/A	N/A	N/A	N/A	N/A
	5.1	5.0	(3.0, 6.0)	4.8	5.0	(3.0, 6.0)	4.5	5.0	(3.0, 6.0)	4.6	5.0	(3.0, 7.0)

Note: GP clinics do not perform the abdominal examination.

Range of possible scores for both test objects is a minimum score of zero objects and a maximum score of eight objects.

between different systems or between a given system and a recognised standard can conveniently be done using the phantoms.

Entrance surface dose

For the adult chest X-ray examination, the median ESD values differ by up to 32% for the range of tube potential from 84 to 100 kVp among the three facility types. It has been reported that increasing the tube potential from 60 to 90 kVp results in 60% reduction of the ESD⁽¹⁵⁾. The use of high kVp techniques (100–140 kV) has contributed to lower doses in the hospital setting in the USA⁽¹³⁾. A possible explanation could be that public hospitals had the highest median beam quality compared with the median values for the other two facility types. The sporadic usage of grids among facilities for all facility types (Table 1) partly explains the broad range of ESD values. The observation that nearly every surveyed public hospital uses a fast (400 or higher) screen–film combination speed likely explains the lower median ESD for these facilities. Anti-scatter grids were used in very few (3/28) of the surveyed GP clinics. The observation that GP sites were found to have comparable image quality to public and private hospitals despite the low use of grids is surprising. The *higher* ESD for GP sites on average (Figure 3) indicates that these sites may tend to have sub-optimal film processing and must, therefore, use a *higher* radiographic technique to compensate. These findings indicate that the image quality at GP sites is likely not optimised with respect to the patient dose.

For the adult abdominal X-ray examination, the median ESD values differ between the two facility types by up to 16% with the tube potential from 67 to 70 kVp. Beam quality (HVL, Table 3) was found to be consistent between facility types.

Public hospitals demonstrated the lowest variability in ESD for both the chest and abdominal examinations. While it is difficult to isolate particular technical parameters that can explain this observation, the quality of radiographic film processing—a parameter that was not evaluated in this study—can impact directly on the ESD⁽¹⁴⁾.

Image quality

Differences in the median film OD observed between facility types may be partly explained by the preference of the radiologist. The authors found that for both the adult chest and abdominal X-ray examinations, despite having a different exposure technique and screen–film combination speed, all facility types have similar median values for spatial resolution and low-contrast detectability. A factor in clinical image quality that was not captured during

Table 5. Phantom film background OD for adult chest and abdominal X-ray examinations.

Parameters	Examination					
	Chest			Abdomen		
	Phantom film OD			Phantom film OD		
	Mean	Median	Range (minimum, maximum)	Mean	Median	Range (minimum, maximum)
Public hospital	1.52	1.57	(1.0, 1.8)	1.54	1.62	(1.0, 2.10)
Private hospital	1.74	1.80	(1.5, 1.9)	1.61	1.67	(1.0, 2.10)
GP clinic	1.48	1.49	(0.9, 2.34)	N/A	N/A	N/A
All	1.56	1.60	(0.9, 2.44)	1.57	1.64	(1.0, 2.10)

Note: GP clinics do not perform the abdominal examination.

the survey is routine QC–QA with regard to viewbox performance and viewing conditions—activities that are recommended components of the technologist’s QC programme⁽¹⁶⁾. The authors conclude that there is still room for optimising radiographic techniques, thereby reducing dose while maintaining acceptable image quality.

Comparison with other studies

Results of the ESD from the present study are compared with those of similar recent studies in Table 6. Ng *et al.*⁽⁸⁾ evaluated the ESD to patients in Malaysia for 131 adult chest and 99 abdominal X-ray examinations using thermoluminescent dosimeters attached to the patient’s skin. They reported median ESD values of 0.30 mGy for the adult chest examination and 9.9 mGy for the abdominal examination. These median values are much higher than those for the present study—0.19 and 3.07 mGy, respectively. Ramli *et al.*⁽¹⁷⁾ reported a median ESD with backscatter of 0.20 mGy for adult chest radiography using computed radiography, comparable to 0.19 mGy in the present study. The median ESD for the adult chest and abdominal X-ray examinations obtained from this study are lower than those recommended by the National Radiation Protection Board⁽¹⁸⁾ and the International Atomic Energy Agency⁽¹⁹⁾. The values are also lower when compared with the mean entrance surface air kerma for the chest (0.33 mGy) and abdominal (3.64 mGy) examinations as reported by Muhogora *et al.*⁽²⁰⁾. The median ESD for abdominal examinations in the present study is also lower than that reported (5.0 mGy) by Ogundare *et al.*⁽²¹⁾. However, mean ESD values reported in the present study are higher compared with the values reported by the NEXT surveys^(22,23). Particularly for the chest examination, this may be due to differences in the selected kV used, where the average kV for the present study was

Table 6. Comparison of estimated ESD with similar estimates from other studies.

Source	Median ESD (mGy)	
	Chest examination	Abdominal examination
US NEXT ⁽²²⁾	0.11 ^a 0.11 ^b	N/A ^c
US NEXT ⁽²³⁾	N/A ^c	2.4
NRPB ⁽¹⁸⁾	0.3	10.0
IAEA ⁽¹⁹⁾	0.4	10.0
Ng <i>et al.</i> ⁽⁸⁾	0.30	9.9
Ogundare <i>et al.</i> ⁽²¹⁾	N/A ^c	5.0
Ramli <i>et al.</i> ⁽¹⁷⁾	0.20	N/A ^c
Muhogora <i>et al.</i> ⁽²⁰⁾	0.33 ^d	3.64 ^d
Present study	0.19	3.07

^aNon-hospitals.

^bHospitals.

^cNot available.

^dMean entrance surface air kerma.

substantially lower than that reported for the US facilities, and the preferred film OD.

The results on image quality assessment from the present study are compared with those of recent NEXT^(13,14,22,23) studies in Tables 7 and 8. It should be noted that the NEXT surveys of abdominal radiography include examinations performed by non-hospital sites. A review of phantom film OD mean values indicates that facilities in Malaysia tend to produce clinical films with a lower background OD than clinical sites in the USA. While the image quality scores for low-contrast (hole patterns) and high-contrast detail (mesh patterns) were comparable to those of the NEXT studies, the observation that low-contrast scores are comparable between the two studies is surprising, given the much lower fraction of facilities in the present study that indicated they

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Table 7. Comparison of image quality findings from the present study with those reported in the NEXT surveys for the chest X-ray examinations.

Parameters		2001 NEXT ⁽²²⁾ (mean)	Present study (mean)
Phantom film OD	Hospital	1.59	Public hospital: 1.52 Private hospital: 1.74
	Non-hospital	1.75	GP clinic: 1.48
Image quality holes visible	Hospital	4.8	Public hospital: 5.8 Private hospital: 4.6
	Non-hospital	4.7	GP clinic: 5.0
Image quality mesh patterns visible	Hospital	5.0	Public hospital: 5.2 Private hospital: 5.3
	Non-hospital	4.7	GP clinic: 5.0

Table 8. Comparison of image quality findings from the present study with those reported in the NEXT surveys for the abdominal X-ray examinations.

Parameters		2002 NEXT ⁽²³⁾ (mean)	1987 NEXT ⁽¹²⁾	Present study (mean)
Phantom film OD	Hospital	1.76	1.80	Public hospital: 1.62 Private hospital: 1.67
	Non-hospital	1.89	N/A	N/A
Image quality holes visible	Hospital	5.2	N/A	Public hospital: 4.8 Private hospital: 4.6
	Non-hospital	5.1	N/A	N/A
Image quality mesh patterns visible	Hospital	4.2	N/A	Public hospital: 4.5 Private hospital: 4.5
	Non-hospital	3.7	N/A	N/A

N/A, no data available.

use grids, which tend to improve radiographic low-contrast performance. Finally, the fact that mean ESD values in this study were on average larger than those of the comparable NEXT studies, especially given the lower frequency of grid use in the surveyed sites in Malaysia, indicates that facilities are likely adjusting their radiographic technique to compensate for an under-optimised radiographic imaging chain.

CONCLUSION

In conclusion, the results of this survey clearly show that there is room for further improvement in performing chest and abdominal X-ray examinations in Malaysia. The results can lead to optimisation on both sides of the risk–benefit equation: better image quality at a lower dose to the patient (and clinical workers as well). It may also serve to add demographic information to issues regarding reference levels and to the worldwide use of radiographic imaging equipment in level II countries.

ACKNOWLEDGEMENTS

The authors acknowledge the support and co-operation from all radiologists, medical physicists and radiographers from those medical facilities that took part in this study. The authors also thank the Director General of Health of Malaysia for his support and interest in this project.

FUNDING

We acknowledge the research grant F-vote from the University of Malaya.

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