Status of radiation protection in various interventional cardiology procedures in the Asia Pacific region

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ABSTRACT

Objective Increasing use of interventional procedures in cardiology with unknown levels of radiation protection in many countries of Asia-Pacific region necessitates the need for status assessment. The study was part of an International Atomic Energy Agency (IAEA) project for achieving improved radiation protection in interventional cardiology (IC) in developing countries.

Design The survey covers 18 cardiac catheterisation laboratories in seven countries (Bangladesh, India, Malaysia, Myanmar, Singapore, Thailand and Vietnam). An important step was the creation of the 'Asian network of Cardiologists in Radiation Protection' and a newsletter. Data were collected on: radiation protection tools, number of IC laboratories, and annual number of various IC paediatric and adult procedures in the hospital and in the country. Patient radiation dose data were collected in terms of Kerma Area Product (KAP) and cumulative dose (CD).

Results It is encouraging that protection devices for staff are largely used in the routine practice. Only 39% of the angiographic machines were equipped with a KAP meter. Operators' initial lack of awareness on radiation-protection optimisation improved significantly after participation in IAEA radiation-protection training. Only two out of five countries reporting patient percutaneous coronary intervention radiation-dose data were fully within the international guidance levels. Data from 51 patients who underwent multiple therapeutic procedures (median 2—3) indicated a total KAP reaching 995 Gy.cm^2 (range 10.1—995) and CD 15.1 Gy (range 0.4—15.1), stressing the importance of dose monitoring and optimisation.

Conclusions There is a need for interventional cardiology societies to play an active role in training actions and implementation of radiation protection.

INTRODUCTION

Interventional cardiology (IC) procedures have become routine and are currently performed in numerous hospitals not only in the Western societies but also in the Asia-Pacific region exhibiting frequencies that increase exponentially every year.[1 2] Apart from diagnostic examinations such as coronary angiography (CA), remarkable progress has also been observed in therapeutic procedures such as percutaneous coronary intervention (PCI), catheter-based structural heart intervention, electrophysiological studies and arrhythmia ablation.[3] Modern x-ray equipment together with improvements in techniques and devices has facilitated cardiologists, pledging more successful clinical outcome and patient safety, thus resulting in a profound change in the treatment of coronary heart disease. It should be noted, however, that these procedures involve high radiation doses not only to the patient[4] but also to the staff.[5] High radiation doses can accumulate very easily because of the extended fluoroscopy times needed to monitor the devices to the area of interest and the large cine recording. As quoted in the recently published European Commission 'Safety and Efficacy for New Techniques and Imaging Using New Equipment to Support European Legislation' project workshop proceedings,[6] 'The collective dose to the population from an IC or radiology facility is comparable with the dose to the entire population of Europe from a nuclear processing plant.' Furthermore, interventional cardiologists run the risk of developing cataracts after many years of work, if proper protection measures are not employed.[7] Paediatric interventional procedures have become very popular in the last few years because of the successful treatment of many congenital and structural heart problems. The downside of this success is the radiation risk to children, owing to their higher radiosensitivity than that of adults and longer mean lifetime expectancy.[8]

Historically, there has hardly been radiation protection training for the majority of Asian interventional cardiologists.[2] Furthermore, very little data on knowledge and practice of radiation protection among interventional cardiologists is available from Asia.[9] There is a gross lack of information on radiation doses to interventional staff because of a lack of use of personnel monitoring devices, partial or minimal use where available, or no knowledge about the dose in badge reports. Increasingly interventional cardiologists are realising the need for training in radiation protection.[9] It continues to surprise many interventionalists that radiation injuries can occur, underlying possible legal action for both the operator and the hospital.[10] In particular, chronic radiodermatitis may result in painful and resistant ulceration, and eventually squamous cell carcinoma.[4] It is still surprising for many cardiologists that a cumulative air-kerma of up to 30 Gy can be recorded in repeated interventional procedures. There is a report of chronic radiodermatitis in two patients who underwent only two cardiac catheterisations performed by experienced operators with an individual case volume of over 200 patients per year, using up-to-date modern digital equipment, meeting current radiation safety guidelines, properly maintained, as well as having a quality assurance programme, in a Western European country.[4]

The International Atomic Energy Agency (IAEA), through its mandate of developing standards of radiation safety and applying these standards in member states,[11] has taken the lead in starting training courses in radiation protection specifically dedicated to interventional cardiologists. Many cardiologists who participated in IAEA training courses have taken the lead in organising training courses in their respective countries. With the realisation of a greater need for interaction among cardiologists, it has also initiated a project under its Regional Cooperative Agreement for Asia programme to create a network of IAEA-trained cardiologists who will spearhead activities in the region through cardiology societies. The Regional Cooperative Agreement for Asia and the Pacific has 17 member states (Australia, Bangladesh, China, India, Indonesia, Japan, Republic of Korea, Malaysia, Mongolia, Myanmar, New Zealand, Pakistan, Philippines, Singapore, Sri Lanka, Thailand and Vietnam). However, only the developing countries among these were participating in this project. There is a lack of information about the status of radiation protection in IC in the region. The objective of the project is to develop a strategy for achieving improved radiation protection in IC, implement the strategy and assess improvement. It includes the following actions: (1) creation of awareness through training courses; (2) monitoring of the practice (or lack thereof) of radiation protection in cardiac catheterisation procedures; (3) creation of network of cardiologists in radiation protection; and (4) wider communication among the community of interventional cardiologists and dissemination of the message of radiation protection. Some results of this project are presented here.

MATERIALS AND METHODS

The project started in 2007, and the first meeting was held in Kuching, Malaysia (17–18 March 2007). The meeting was attended by one cardiologist from each of the 10 following countries: Bangladesh, China, India, Indonesia, Malaysia, Myanmar, Mongolia, Singapore, Thailand and Vietnam. Thus, this report covers primarily the developing countries in Asia and Pacific. Prior to this action, the IAEA had started training of cardiologists in 2004 under other projects on radiation protection. The first action decided under the RCA project was the creation of the network of Asian Cardiologists in Radiation Protection and launch of a newsletter for strengthening communication on radiation protection. Seven issues of this newsletter have been issued so far and are available online.[2] To the best of our knowledge, this is the first ever newsletter on radiation protection devoted to IC and being maintained by cardiologists themselves. Also, a set of prospective data-collection forms was developed by the IAEA, giving standard instructions and protocols to receive information from interventional cardiologists in a comparable and meaningful way. The cardiologists from different countries were asked to provide data on:

1. The number of cardiac catheterisation laboratories in each participating hospital and country.
2. The annual numbers of selected diagnostic and therapeutic interventional procedures (as listed in item 6 below) in both the paediatric and adult population in the individual participating hospitals and country in years 2003 and 2006, to gain an insight into the trend of interventional procedures in the participating countries in the Asia and Pacific region.
3. The various radiation protection tools applied in the catheterisation laboratory such as the use of lead glass eye wear or a ceiling-suspended screen.
4. The availability of patient dose measurement tools such as a Kerma Area Product (KAP) meter and/or cumulative dose (CD) or cumulative air-kerma. Most, if not all, new equipment has this feature of providing dosimetric quantity KAP or earlier called the dose area product (DAP; in Gy.cm^2 or mGy.cm^2) and another value in mGy, ie, generally dose at interventional reference point, also called cumulative dose.
5. Availability and use of personnel monitoring device, such as a thermoluminescent badge, by the operator and those assisting in the angiography room.
6. Data on fluoroscopy time, cine runs, total number of images and patient dose information recorded in terms of KAP (if the x-ray equipment had a KAP meter installed) and/or cumulative dose or air-kerma (for x-ray systems displaying these dose quantities) for selected interventional procedures. A large number of procedures were selected: coronary angiography (CA) without left ventriculography (LV), CA with LV, single-vessel (sv), double-vessel (dv) or triple-vessel (trv) percutaneous coronary intervention (PCI) with or without chronic total occlusion (CTO) as also ad hoc PCI (PCI performed in the same session as CA), percutaneous transvenous mitral commissurotomy (PTMC), closure of atrial septal defect (ASD), patent foramen ovale (PFO) or ventricular septal defect closure, electrophysiological (EF) diagnostic study, supraventricular tachycardia (SVT) or atrial fibrillation ablation and finally automatic implantable cardioverter defibrillator implantation.
   Hospitals were asked to provide information for the procedures routinely performed in their IC laboratories.
7. The level of radiation dose in repeated interventional procedures examined by recording KAP for patients with more than one interventional procedure having been carried out within the study period, or within 4 months prior to study period.
8. The distribution of KAP in either PCI or PCI with CA, using a common protocol. Data were presented in five ranges (number of patients receiving KAP≤100 Gy.cm^2, 101 to 200 Gy.cm^2, 201 to 300 Gy.cm^2, 301 to 400 Gy.cm^2 and ≥401 Gy.cm^2).
9. Collection of information on change in practice introduced in cardiac catheterisation procedures after knowledge gained in IAEA training courses. This is important, as it provides an important analysis of training and provides information about application of knowledge.

RESULTS

Data were submitted to the IAEA during the second meeting of the network of Asian cardiologists and medical specialists in radiation protection, held in Bangkok, Thailand (24–26 June 2008). Seven countries and seven corresponding hospitals have so far provided information: Singapore (National Heart Centre), Vietnam (Choray University Hospital, HCMC), Myanmar (Yangon General Hospital), Malaysia (Sarawak General Hospital), India (Bombay Hospital), Bangladesh (National Institute of Cardiological Disease) and Thailand (King Chulalongkorn Memorial Hospital).

Table 1 presents general information on the number of catheterisation laboratories in the hospital and in the country, as well as the availability and use of various radiation protection tools such as lead flaps, eye wear or lead screens. The table also

Table 1 General information on the number of catheterisation laboratories in each hospital and country, information on radiation protection tools and personnel monitoring

	Singapore	Vietnam	Myanmar	Malaysia	India	Bangladesh	Thailand
No of cath labs in country	14	18	5	50	460	30	44
Population (million)	4.6	84	47	25	1147	153	66
No of cath labs in hospital	4	2	1	1	2	5	3
No of Kerma Area Products in hospital	4	1	0	0	1	0	1
Are lead flaps available?	Y	Y	Y	Y	Y	Y	Y
Are the lead flaps used?	Y	Y	Y	Y	Y	Y	Y
Is eye wear or lead screen available?	Y	Y		Y	Y	Y	Y
Is eye wear used?	Operator-dependent	Y	Y	Y	Y	Y	Y
Personal monitoring	Y	Y	Y	Y	Y	Y	Y
No of dosimeters on operator	1	2	1	2	1	1	1
No of dosimeters on assistant	0	1	1	2	1	1	1
Dosimeter under apron	Y	Y	Y	Y	Y	N	Y
Dosimeter above apron	N	Y	N	Y	N	Y	N

includes data on personal monitoring and specifically the number of dosimeters used as well as the standard location of these dosimeters. The total number of laboratories that were included in the survey was 18 and accounted for 3% of the total laboratories in all participating countries (621 cath labs). Only seven out of 18 (39%) angiographic machines were equipped with a KAP meter. As far as protection tools availability and use are concerned, it is most encouraging that lead flaps, all articulated screens and lead glass eye wear are being used routinely in all participating centres. Although personnel monitoring is routinely carried out by the operators, the number and position of the dosimeters (over or under the apron) differ according to the regulations of the country. For those who wear one dosimeter (71%), they all place it under the apron, apart from one country. In some countries, the main personnel monitor is worn outside the lead apron so as to estimate the radiation dose to unprotected parts of the human body and to monitor exposure to the head, lens of the eye and neck, and to ensure that lens and thyroid dose equivalents are within recommended limits.[12] For operators monitored by two dosimeters, one is placed under the apron at waist level and the other one over the apron at collar level (this dosimeter provides an estimation of thyroid and eye lens doses[12]).

Table 2A shows the annual numbers of patients in participating hospitals for selected interventional procedures: (1) CA, (2) PCI, (3) combined CA+ad hoc PCI, (4) various interventional procedures other than CA or PCI or both, defined as 'other' procedures, and finally (5) paediatric procedures. In general, PCI or ad hoc PCI showed a definite increasing trend with rate of increase ranging from 4.9 to 70.6%. In one hospital, with the availability of coronary CT angiography, there was a 20.2% decrease in diagnostic coronary angiography cases. The annual numbers of patients vary widely between hospitals, for the same type of procedure. As far as the 'other' procedures are concerned, they account for 1.7–33.4% of the total IC procedures within the hospitals. The frequency of 'other' procedures differs between hospitals substantially with a median of 6.3%. It should be noted that the two hospitals that reported the smallest number of IC procedures have also reported the greatest percentage of 'other' procedures. As far as paediatric procedures are concerned, two out of seven centres do not perform paediatric cardiac procedures, one has recently started, and one reported a substantial decrease because of the recent existence of a new paediatric centre in the same region (Bombay Hospital).

Table 2B shows similar data to that of table 2A for the whole country. Five countries succeeded in reporting the annual number of CA and PCI in general. The rates of increase in CA and PCI are substantially high, ranging from 20.0 to 53.3% followed by the 'other' procedures (18.2–32.6%), reported by four out of the seven countries. The 'other' procedures account for 1.5–13.5% of the total number reported by each country with a median of 8%. Paediatric data were more difficult to gather, and only two countries reported annual numbers for the whole country. Available data on paediatric cardiology service show a similar increase in invasive x-ray guided cardiac procedures. Once again, the rate of increase is considerable, 17.5–33.6%, reaching the numbers of 'other' techniques in adult patients.

Table 3 presents the median values of patient age, weight (W), KAP, fluoroscopy time (T), cine runs (R) and total number of images (F) in: (a) CA, (b) CA+LV, (c) PTMC and (d) ASD/PFO closure. Centres equipped with a KAP meter succeeded in reporting dose data. The table also includes one country that submitted only technical data (T, R and F) but did not report the corresponding KAP values. Among the survey centres, the numbers of patients (N) having CA and CA+LV are considerably higher than PTMC and ASD/PFO closure where the numbers of patients are considerably lower. As there are no studies in the recent literature providing dosimetric information or technical data (T, R and F) in these procedures, it was considered helpful to report all submitted data so as to make preliminary observations regarding PTMC and ASD/PFO closures. Not surprisingly, the median age of PTMC and ASD/PFO closure patients ranged between 23 and 42 years of age compared with routine CA and CA+LV (49–69 years), while coronary artery disease has a higher incidence with advanced age, symptomatic rheumatic mitral stenosis and congenital heart defects usually affecting the younger population. For patients with rheumatic mitral valve stenosis, those in developing countries may become symptomatic in their late teens or early twenties, whereas patients in more developed countries have a mean age of presentation in the fifth or sixth decade of life.[13 14] Since the patient age distribution is considerably lower in these therapeutic procedures, it is very important to investigate them in more detail. The median weight in PTMC and ASD/PFO closure patients ranged between 49 and 56 kg, whereas in CA and CA+LV, the corresponding range was 61–70 kg. The table shows a wide variation between centres in T, F and KAP in IC techniques. More predominant are the variations in PTMC and ASD/PFO closure, where KAP variation by a factor of 12 and about seven respectively are evident, and the variation in F (number of images) is by a factor of 6. Initial findings show that PTMC and ASD/PFO techniques

Table 2 Annual numbers of patients in the following interventional procedures in participating hospitals (A) and countries (B): (1) coronary angiography (CA), (2) percutaneous coronary intervention (PCI), (3) CA and PCI, (4) various interventional procedures and (5) paediatric procedures

Country	Hospital (Hs)	Year	PCI	CA	CA+PCI	Other	O (%)*	Paediatric procedures
(A) In participating hospital								
Singapore	National Heart Centre	2003	683	1472	1101	287	8.1	0
		2006	896	1739	1250	413	9.6	0
		Percentage increase	23.8	15.4	11.9	30.5		
Vietnam	Choray University	2003	147	250	87	141	22.6	0
		2006	500	934	175	113	6.6	0
		Percentage increase	70.6	73.2	50.3	−24.8		0
Myanmar	Yangon General	2003	39	98	39	68	27.9	0
		2006	98	101	98	149	33.4	6
		Percentage increase	60.2	3.0	60.2	54.4		100
Malaysia	Sarawak General	2003	328	1426		91	4.9	24
		2006	533	1186		86	4.8	65
		Percentage increase	38.5	−20.2		−5.8		63.1
India	Bombay	2003	896	2517	3413	206	2.9	1363
		2006	1088	2542	3630	283	3.8	984
		Percentage increase	17.6	1.0	6.0	27.2		−38.5
Bangladesh	National Institute of Cardiovascular Diseases	2003	500	3300	3800	740	8.9	350
		2006	900	7500	8300	1065	6.0	350
		Percentage increase	44.4	56.0	54.2	30.5		0
Thailand	King Chulalongkorn Memorial Hospital	2003	662	1222	560	42	1.7	162
		2006	696	1508	600	108	3.7	287
		Percentage increase	4.9	19.0	6.7	61.1		43.6

Country	Year	PCI	CA	Other	O (%)	Paediatric	Total
(B) In participating country							
Vietnam	2003	1256	3858				5114
	2006	2324	5573				7897
	Percentage increase	46.0	30.8				
Malaysia	2003	8000	18 000	450	1.7		26 450
	2006	10 000	25 000	550	1.5		35 550
	Percentage increase	20.0	28.0	18.2			
India	2003	42 000	130 000	17 545	9.3	1723	191 268
	2006	90 000	270 000	26 012	6.7	2596	388 608
	Percentage increase	53.3	51.9	32.6		33.6	
Bangladesh	2003	1400	7800	1440	13.5	660	11 300
	2006	2400	11 000	2090	13.5	800	16 290
	Percentage increase	41.7	29.1	31.1		17.5	
Thailand	2003						
	2006	7633	14 994	936			23 563

*O (%) is the percentage of the annual number of 'other' interventional procedures to the total annual number of IC procedures reported by each hospital.

should be investigated more thoroughly, taking into consideration that dosimetric values are comparable with CA and PCI doses. The technical and dosimetric data for the EF diagnostic study, SVT or atrial fibrillation ablation and automatic implantable cardioverter defibrillator implantation were not reported; also, the numbers of patients were not sufficient from which to draw any conclusions, and so they are not included in this section.

Table 4 shows similar data to that in table 3 specifically for PCI. This means that apart from PCI in general, as reported by the representative centres in the first two countries shown in the table, a certain number of countries reported data separately on single-vessel/double-vessel/triple-vessel PCI with or without chronic total occlusion and with or without CA or CA plus LV. The table shows that if a diagnostic part (CA, or CA+LV) is added in the technique or as the complexity of procedure increases, T, F and KAP also increase. Maximum values of T, F and KAP are seen either in chronic total occlusion PCI or in CA +LV+chronic total occlusion PCI. This reveals the need for a more detailed study on a higher number of patients on the types of PCI and especially in PCI for chronic total occlusion (CTO). This is especially important in East Asian countries where there has been increasing interest in chronic total occlusion PCI owing to recent advances in CTO PCI devices and strategies. Some patients for CTO PCI also undergo pre-PCI coronary CT angiography. This practice incurs additional radiation dose to the patient and deserves further study. One country (India) reported a high F in the range of 4086−9119, and the reason stated by the participant was the need to see a distal artery in the long lesion thrombotic lesions and chronically occluded arteries.

Table 5 presents median and range of KAP and cumulative dose (CD) for patients having more than one PCI done within the study period. The median number of repeated PCI procedures was two within the study period. The median KAP range was 73.4−196.0 Gy.cm^2, and the CD range was 1.9−3.0 Gy. The range of KAP and CD in the whole sample, however, was much higher (KAP: 10.1−995.0 Gy.cm^2; CD: 0.4−15.1 Gy) showing the importance of patient dose monitoring and optimisation.

Table 3 Fluoroscopy time, cine runs, total number of images and Kerma Area Product in median values are shown in this table for selected interventional procedures (coronary angiography without left ventriculography, coronary angiography with left ventriculography, percutaneous transvenous mitral commissurotomy, closure of atrial septal defect or patent foramen ovale)

Country	No of procedures	Age (years)	Median weight of patients (kg)	Fluoroscopy time (min)	Cine runs	Total no of images	Kerma Area Product ($Gy.cm^2$)
(A) Coronary angiography							
Singapore	259	60	67	2.5	8	774	35
Thailand	54	69	61	5.9	9.6		47
India	150	55	66	3.2	8	1192	
Bangladesh	24	55	60	3.82	9.6	542	14.8
(B) Coronary angiography+left ventriculography							
Singapore	122	59	66	3.4	9	892	36.2
Vietnam	347	59		5.6	7.9	487	9.1
Thailand	38	60	69	4.6	9.3		47
India	236	54	70	3.4	8	1206	
Bangladesh	6	49	60	5.2	11	805	14.7
(C) Percutaneous transvenous mitral commissurotomy							
Vietnam	18	33		5.1		361	3.5
Thailand	43			29	5		41
India	21	27	56	8	5	758	
(D) Atrial septal defect/patent foramen ovale closure							
Vietnam	14	23		11.4		232	11
Thailand	5	42	55	22.4	7.6		74
India	4	24	49	16	9	1429	

Guidance levels for coronary angiography: Kerma Area Product: 50 $Gy.cm^2$; fluoroscopy time: 9 min; total number of images: 1000 images.[26]

Figure 1 shows the distribution of KAP in PCI (A) without CA and (B) with CA. As shown in figure 1A, three out of four countries submitting data for PCI reported a KAP of <100 $Gy.cm^2$ (74.4–98.3%). This is encouraging, since the KAP trigger level likely to cause skin erythema is at 300 $Gy.cm^2$, and this corresponds to a skin dose of approximately 2 Gy when the contributions of CA and PTCA together are considered.[15] One country reported a substantial number of PCIs (26.7%) with a KAP of >400 $Gy.cm^2$, revealing the need for dose optimisation. A considerable number of values were in the range of 101–200 $Gy.cm^2$ (1.7–14.6%). Overall, it should be noted that most of the KAP values in this study were below the trigger level (66.7–100%) for PCI. The majority of KAP values are below the trigger level (95.1–99.7%) in PCI with a diagnostic part (CA) with 63.2–97.6% of data below 100 $Gy.cm^2$.

Finally, table 6 shows the change in situation or practice reported by participating centres regarding radiation protection. It is remarkable that seven out of seven respondents (100%) started to avoid irradiation of same area in order to achieve skin sparing six out of seven (86%) started recording fluoroscopy time; five out of seven (71%) reported that they had changed the practice by trying to keep the x-ray tube away from the patient, avoidance (as far as possible) of steep angulations, reducing cine duration and fluoro time and avoiding unnecessary movement of the staff in the cath lab; four out of seven (57%) started keeping the image intensifier near the patient, using a lower magnification and starting recording patient dose in terms of KAP. The changes in other parameters, particularly those pertaining to staff protection, were much less than above.

DISCUSSION

The number of catheterisation laboratories in participating countries (range: 5–460; median: 30; max/min ratio: 92) differs enormously between countries. This finding is very important, since little dosimetric information exists in the literature, even for developed countries. The European Society of Cardiology[16] and a number of national organisations in different parts of the world[17,18] have carried out surveys in recent years, but they lack the radiation dose information, as the focus is on change in situations with respect to the number of different procedures. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) is an organisation that performs surveys periodically, including radiation-dose estimates, such as the 2088 report released in 2010.[19] The UNSCEAR survey, however, has very limited information on the number of catheterisation laboratories across the world and related patient doses. According to the British Heart Foundation Statistics Database report from 2005,[20] the number of interventional centres in UK in 2003 was 73, a value comparable with corresponding numbers reported by three out of seven developing countries in this study (30, 44 and 50 catheterisation laboratories in each of the three countries in table 1).

As far as radiation protection tools are concerned (table 1), the comparatively low percentage of KAP meters in cath labs (39%) is expected in view of the low awareness of the need to monitor radiation dose to the patient. This may partly be due to the presence of older angiographic machines without an internally installed KAP meter. Another important reason is the lack of regulatory enforcement for the need to have a radiation-dose monitoring system in place for new angiographic machines in cardiac catheterisation laboratories in most participating countries. National regulations governing radiation protection should be modified so as to include mandatory requirements for the installation and use of dose meters in all catheterisation laboratories. This will facilitate radiation protection of the patient, as monitoring dose is an excellent tool and results in inculcating a safety culture.[21,22] It is interesting to note that there is good awareness and concern for staff protection, as protective aprons and collars, lead flaps, articulated screens and lead glass eye wear are used routinely in all participating centres, probably because of the IAEA programmes in developing countries including training courses. In this respect, catheterisation laboratories in participating developing countries are currently comparable

Table 4 Fluoroscopy time (T), cine runs, total number of images (F) and Kerma Area Product (KAP) in median values for selected interventional procedures: (A) percutaneous coronary intervention (PCI); (B) single-vessel (sv) PCI; (C) double-vessel (dv) or triple-vessel (trv) PCI; (D) chronic total occlusion (CTO) PCI, without or with a diagnostic part (CA, CA+LV)

Country	Procedure	No of procedures	Age (years)	Median weight of patients (kg)	T (min)	Cine runs	F	KAP ($Gy.cm^2$)
Singapore	PCI	101	62	66	12.3	24.4	1144	56.5
	CA+LV+PCI	237	63	67	10	26.5	1502	69.8
Vietnam	PCI	153	60		7.1		359	15.9
	CA+LV+PCI	90	60		7.8		581	16.1
Thailand	CA+sv PCI	43	60	70	8	25		77
	CA+LV+sv PCI	3	61	56	11	29		90
	CA+dv/trv PCI	15	68	65	14	44		130
	CA+LV+dv/trv PCI	1	75		18	30		172
	CA+CTO PCI	8	67	74	47	56		318
	CA+LV+CTO PCI	2	54	65	38.5	22		219
	sv PCI	8	61	60	6	14.5		50
	dv/trv PCI	2	63	66	11	23		43
	CTO PCI	5	68	59	92	109		513
India	CA+sv PCI	24	51	66	8	27	4114	
	CA+LV+sv PCI	60	52	62	8	26	4086	
	CA+dv/trv PCI	8	57	69	11	44	7016	
	CA+LV+dv/trv PCI	20	55	65	11	46	7193	
	CA+CTO PCI	5	63	70	20	20	8903	
	CA+LV+CTO PCI	3	66	74	20	20	9119	
	sv PCI	13	56	73	6	6	3856	
	dv/trv PCI	9	58	72	10	10	6934	
	CTO PCI	4	60	76	21	21	9067	
Bangladesh	CA+sv PCI	1	50		15.59	11	468	82.8
	CA+LV+sv PCI	1	47		10.20	31	1036	77.1
	CA+dv/trv PCI	1	47		12.19	28	1473	78.5
	CA+LV+dv/tr PCI	1	48		13.08	38	1470	82.7
	CA+CTO PCI	1	60		15.03	15	1200	80.3
	CA+LV+CTO PCI	1	58		23.26	33	1442	81.4

Guidance levels for PCI: KAP: 125 $Gy.cm^2$; T: 22 min; F: 1700 images[13]; simple KAP: 100 $Gy.cm^2$; T: 15 min; F: 1500 images[13]; medium KAP: 125 $Gy.cm^2$; T: 22 min; F: 1700 images[13]; complex KAP: 200 $Gy.cm^2$; T: 32 min; F: 2300 images.[13]

with western laboratories. On the other hand, it would be interesting to know if the aforementioned radiation protection tools are used correctly and regularly. This information would be difficult to establish using postal surveys, as there is always the element of projection" (in postal surveys you make estimations since you receive small number of answers). It is heartening to note frank and sincere expression by cardiologists in the various newsletters.[2 9] As reported in the second issue of the newsletter of the Asian Network Cardiologists in Radiation Protection, many interventional cardiologists in Asia have no idea of the correct positioning of the patient in relation to the image receptor, and the x-ray source itself can reduce the radiation dose to the patient.[9] This clearly shows the importance of training in radiation protection, as seen from the experience of the IAEA.[23–26] Some of the members of the network have started including radiation protection in live demonstrations in national and international conferences.[27]

This study shows that IC procedures are increasing in developing countries, as also shown by the results of another IAEA project covering 20 countries.[26] The current study, however, is focused on the Asia-Pacific region to provide a clearer picture of the situation in this part of the world. The overall trend shows that an increasing number of countries in the Asian-Pacific region, even with limited resources, are performing more and more often adult interventional procedures. Furthermore, this study distinguishes between various IC procedures showing a distinct increase in not only the standard CA and PCI techniques mostly reported in the literature but also 'other' diagnostic and therapeutic IC procedures. In this study, annual numbers within each hospital and country are reported. It is interesting that the rate of increase in PCI with or without CA ranges between 20.0 and 52.2% in the Asia-Pacific region, whereas in Europe, the corresponding rates are 3.78–11.82% in 2007, as reported by Faulkner in 2008.[28] The total numbers of

Table 5 Median (range) values of Kerma Area Product and cumulative dose in patients having undergone more than one percutaneous coronary intervention

Country	No of patients	Median no of percutaneous coronary interventions	Kerma Area Product ($Gy.cm^2$)	Cumulative dose (Gy)
Singapore	8	2	178.5 (61.3 to 421.9)	
Vietnam	8	3	73.4 (10.1 to 250.6)	1.9 (0.4 to 3.8)
Thailand	29	2	196 (33 to 995)	3.0 (0.6 to 15.1)
Malaysia	6	2	175.3 (106.1 to 253.6)	

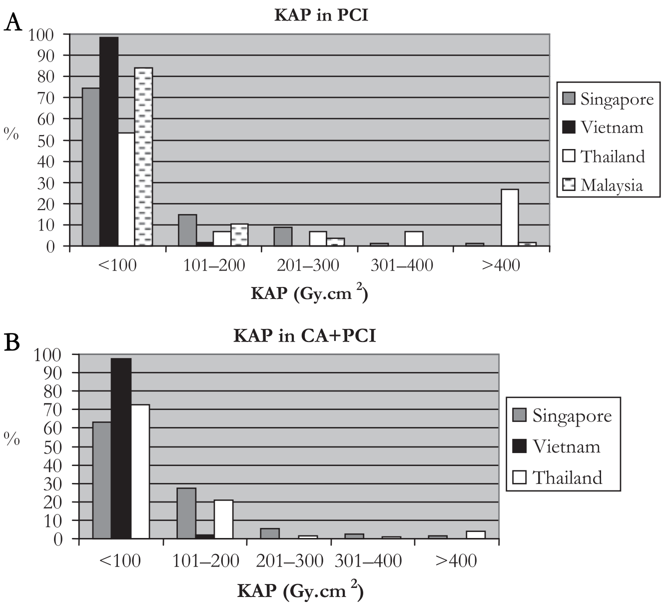

Figure 1 Distributions of Kerma Area Product (KAP) in (A) percutaneous coronary intervention (PCI) and (B) coronary angiography (CA)+PCI presented in five ranges (number of patients receiving KAP ≤100 Gy cm^2, 101−200 Gy cm^2, 201−300 Gy cm^2, 301−400 Gy cm^2 and ≥401 Gy cm^2).

CA and PCI procedures reported in 2006 by most participating Asian countries reach the level of many Eastern European countries, whereas one Asian country reported data similar to that for Italy, a country of the Western world.[13] The total number of procedures in participating countries succeeding in reporting data was 471 908 in 2006 (range: 7897−388 608 IC procedures). An UNSCEAR 2000 report presented similar information only for Spain in the year 1997, with a total of 90.915 procedures.[19] A recent paper detailed a survey of the situation in 20 developing countries.[26] This shows that more information is required on the total number of procedures across the world, as the possibility of developing countries in the Asia-Pacific region reaching the frequencies of countries with well-established healthcare systems cannot be ruled out. It should be noted that the data reported by Faulkner in 2008[28] were estimated by regression analysis and extrapolation, whereas this study reports the actual annual numbers in participating countries.

A comparison of doses with the literature could only be done for CA and PCI. No similar data were found for PTMC and ASD/PFO closure procedures, showing that this study is the first dosimetric investigation on these procedures. It should be stressed, however, that because the level of patient radiation dose for PTMC and ASD/PFO closures reaches those of CA and PCI, there is an urgent need for a more detailed investigation in the immediate future. Radiation doses were compared with guidance levels (GL) recently published for CA (KAP: 50 Gy.cm^2; T: 9 min; F: 1000 images) and PCI (KAP: 125 Gy.cm^2; T: 22 min; F: 1700 images).[29] As shown in table 3, all reported data for CA and CA+LV are within GL. Balter and colleagues[29] also proposed action levels for CA (KAP: 15 Gy.cm^2; T: 2 min; F: 500 images) and PCI (KAP: 25 Gy.cm^2; T: 5 min; F: 400 images) below which centres should investigate the quality of the procedures. This is very important, since overzealous dose reduction may lead to poor images and be detrimental to the clinical outcome. On the other hand, too low a dose may indicate an incomplete

Table 6 Survey of situation of radiation protection in interventional cardiology in Asian countries

Actions	Before participation in International Atomic Energy Agency course Y/N	After participation in International Atomic Energy Agency course Y/N	Change in situation or practice reported by following no of respondents out of seven listed below*
Staff protection			
Use of thyroid shield	N	Y	1
Use of two personal monitoring badges: one below the lead apron and another at collar level	N	Y	2
Lead glasses eye wear	N	Y	3
Lead flaps for legs protection	N	Y	3
Any unnecessary movement of people in the cath lab	Y	N or sometime	5
Any awareness of where x-ray comes from	N	Y	2
Is there a system?			
Regular testing of protective devices (eg, lead apron) (Y/N)	N	Y	1
Routine QC testing of angio machine (Y/N)	N	Y	2
Any liaising with medical physicist (Y/N)	N	Y	1
Changes in technique (by operator actions)			
Keep x-ray tube away from patient	N	Y	5
Keep image intensifier near patient	N	Y	4
Fluoro recording (Y/N)	N	Y	6
Avoidance (as far as possible) of steep angulations (Y/N)	N	As much as possible	5
Use of lower frame rate/pulse rate (Y/N)	N	Y	3
Use of lower magnification (Y/N)	N	Y	4
Proper wedge filter positioning (Y/N)	N	Y	3
Collimation (Y/N)	N	Y	2
Avoiding irradiation of same area to achieve skin sparing (Y/N)	N	Y	7
Reducing cine duration and fluoro time (Y/N)	N	Y	5
Patient dose measurement			
Kerma Area Product	N	Y	4
Skin dose	N	Y	2
Cumulative air kerma	N	Y	2

*Countries that responded to survey: Bangladesh, India, Malaysia, Myanmar, Singapore, Thailand, Vietnam (alphabetically)=7.

procedure, low complexity or even excellent technical settings.[29] As demonstrated by Kuon, it is possible to reduce KAP below action levels without affecting quality.[30] At the very end, low-dose action levels can help trigger an investigation as to whether images of insufficient quality are used.[29] Two out of four countries reported KAP values below action levels (9.1 and 14.7 Gy. cm^2). With regard to PCI (table 4), data are variable. Fluoroscopy times are below GL except for one hospital (Thailand), with values for CTO PCI (T=92 min) much higher even than the GL for complex procedures (KAP: 200 $Gycm^2$; T: 32 min; F:2300 images).[29] However, the total number of patients was too low to draw safe conclusions (fewer than 10 patients). Results of this kind provide an opportunity to compare the situation with others and achieve optimisation. The total numbers of frames reported by participating hospitals were below GL, except again for one hospital in a different country than previously found that reported F values 2.3–5.3 times higher than the GL. Since most of the radiation dose is due to cine dose, this creates grounds for optimisation of PCI procedures by reducing the number of frames taken. With regard to dosimetric data, there are countries with KAP values below GL and one country with a KAP value below action levels, but the absence of calibration of KAP in the country makes it difficult to gain a true picture. One country reported KAP values in CTO PCI much higher than that of the GL, and they were advised to take appropriate optimisation action. It is clear that most participating hospitals need to optimise their techniques to lower patient doses. Only two out of five countries reporting data were fully within GL, one of which reported results for only one patient. On the other hand, it is most encouraging that the median KAP values in patients with more than one PCI were below GL (table 5). The wide range of doses reported, however, in those patients and the above findings call for immediate optimisation in laboratories.

Despite the IAEA's initiatives, it will take a long time for the message to penetrate, with the growing number of newcomers in the field, and any change in the real situation would take many years. Most of the operators did not know how best to use the x-ray machine for radiation-protection optimisation before the IAEA courses. Since the level of knowledge in radiation protection in these countries is not well known or does not exist, it is evident that training activities should be emphasized in these countries. It is worth mentioning that actions such as keeping the x-ray tube away from the patient, avoiding steep angulations as much as possible or reducing fluoroscopy time and cine duration do not impose additional costs to the IC department and are well known to save substantial amounts of radiation to the patient and also to the staff in the cath lab. Since the importance of radiation-protection training courses has been repeatedly stressed by the IAEA,[23–26] more effort should be made by IC societies, in collaboration possibly with the IAEA, to create awareness of radiation protection among members. The IAEA has made available training material on its website for free download, and this is one of the best resources that cardiologists can use, as this material has been tested for more than 4 years in a large number of training courses. The material has also been endorsed by WHO, SCAI and the International Organization of Medical Physicists. Senior cardiologists with no training or very limited knowledge on the use of modern x-ray technology should have the opportunity in international conferences, meetings, live courses, regional and national cardiology conferences to find out more about the practical aspects of radiation protection. This should be part of continuous professional development. Adequate training and credentialling provide well-known methods for managing issues of training and experience.'[22]

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