The Average Collective Equivalent Dose and Fatal Cancer Risk for Radiation Workers in Radiology Department at Phramongkutklao Hospital, 2004-2008

Supakajee Saengruang-Orn PhD*,
Manus Mongkolsuk MSc**, Thanpong Rangsiphat MD*

** Department of Radiology, Phramongkutklao Hospital, Bangkok, Thailand*
*** Faculty of Medical Technology, Mahidol University, Bangkok, Thailand*

Objective: *To evaluate the five years average equivalent dose, the average collective equivalent dose and fatal cancer risk for the radiation workers in Radiology Department at Phramongkutklao Hospital.*
Material and Method: *In the Radiology Department at Phramongkutklao Hospital, occupationally exposed workers are measured by the Division of Radiation Protection Services, Department of Medical Sciences which measures radiation exposures and evaluated doses from external exposures. Individual's doses of external exposure were monitored using film badges. The present study design describes a retrospective survey of occupational exposure in the Radiology Department at Phramongkutklao Hospital 2004-2008.*
Results: *The distribution of radiation workers monitored according to the groups in the years 2004-2008, physicist, technologist and assistant of technologist were the most numerous occupational group (51.13%). Nurse, assistant of nurse and nurse aids constituted 22.73%. About 59.73% of radiation workers in the Radiology Department at Phramongkutklao Hospital received an annual average equivalent dose below 0.02 mSv which defined as recording level and no radiation workers received doses above the International Commission on Radiological Protection (ICRP) Publication 60 recommended dose limit (20 mSv per year). The five years average equivalent dose per radiation worker was 1.098 mSv. Of all occupational groups measurably exposed, the nuclear medicine group received the highest of the five years average equivalent dose, collective equivalent dose and fatal cancer risk. The five years average equivalent dose, collective equivalent dose and fatal cancer risk for the physicist, technologist and assistant of technologist were the highest.*
Conclusion: *Total risk per the whole monitored radiation workers were 3.86×10^{-3} due to receive the five years average collective equivalent dose 0.096 man Sv. These values were estimated from a very small of number of radiation workers.*

Keywords: *Equivalent dose, Collective equivalent dose, Fatal cancer risk, Dose limit*

J Med Assoc Thai 2012; 95 (Suppl. 5): S96-S102
Full text. e-Journal: *http://jmat.mat.or.th*

Reports on serious somatic effects in radiologists and radiological technologist in the early use of x-rays are numerous[1]. In addition, late effects were also demonstrated in studies of the mortality of British and American radiologists[2-5]. The cancers induced by radiation, with or without a contribution from other agents, are not distinguishable from those occurring from other causes. The defense mechanism is not likely to be totally effective, even at small doses[6].

Since the probability of cancer resulting from radiation is related to dose, this type of radiation effect can only be detected by statistical means in epidemiological studies carried out on exposed population groups. If the number of people in an irradiated group and the doses that they have received are known and if the number of cancers eventually observed in the group exceeds the number that could be expected in an otherwise similar but nonirradiated group, the excess number of cancers may be attributed to the effects of the irradiation and the risk of cancer per unit dose may be calculated. This number is called a risk factor[7]. Cancer risks derived from such exposed groups are based largely on exposures to high doses delivered over a short period of time. However, in practice most cases of radiation exposure are to low levels of radiation over relatively long period. These considerations led the International Commission on Radiological Protection (ICRP) to establish a risk factor or lifetime fatality probability coefficient for a reference population

Correspondence to:
Saengruang-Orn S, Department of Radiology, Phramongkutklao Hospital, 315 Rajavithee Road, Bangkok 10900, Thailand.
Phone: 0-2354-7600 ext. 93813, Fax: 0-2354-5243
E-mail: s_supakajee@yahoo.com

of both sexes and a working age of 4 x 10^{-2} Sv^{-1} $(sievert)^{-1}$ for the sum of all fatal malignancies[8].

The ICRP Publication 60 recommended a limit on effective dose of 20 mSv per year, averaged over 5 years (100 mSv in 5 years), with the further provision that the effective dose should not exceed 50 mSv in any single year[8,10]. So, National Regulation and international recommendation have always emphasized the use of individual monitoring as a tool for the control of doses to radiation workers. Collections of individual doses can be useful to provide statistical information on the current situation and trend of equivalent doses[9].

In the Radiology Department at Phramongkutklao Hospital, measurements of individual occupational exposures recorded by film are reported to wearers as equivalent dose, its unit is mSv. The accuracy of measurement is $\pm$ 20%. These measurements have been carried out centrally by the Division of Radiation Protection Services, Department of Medical Sciences. Individual's doses of external exposure were monitored using film badges. The minimum detectable level was 0.02 mSv for x-ray and 0.15 mSv for γ and β-ray. The monitoring films were the Eastman Kodak Type 2 film and the NRPB/AERE film holder system.

Films offer the advantages of providing a permanent record, indicating the approximate energy of the radiation to which the dosimeter was exposed where this is unknown and showing the presence of contamination from unsealed radionuclide[10]. Where a significant exposure has been received the film record will also indicate whether this has been accumulated over a period of work or as a short, single exposure (when the film holder filter shadows are sharply defined) which might indicate a occupational or deliberate irradiation of the dosimeter[11,12].

The primary objectives of the present study were: (1) To calculate fatal cancer risk for the radiation workers. (2) To estimate the five years average equivalent dose per worker and the average collective equivalent dose for the radiation workers such as physician, technologist and nurse.

The present study design describes a retrospective survey of occupational exposure in the Radiology Department at Phramongkutklao Hospital based on doses reported by the Division of Radiation Protection Services, Department of Medical Sciences.

Material and Method

Data Collection

In the Radiology Department at Phramongkutklao Hospital, the level of radiation exposed among exposed workers that were classified by occupational groups such as physician, technologist and nurse were measured by the Division of Radiation Protection Services, Department of Medical Sciences which measures radiation exposures and evaluated doses from external exposures. Individual doses of external exposure were monitored using personnel dosimeter film badges for the 2004-2008 periods.

Statistical analysis

The five years average equivalent doses for each group per radiation worker such as diagnostic, radiotherapy and nuclear medicine division are defined as:

$$X = (1/5)\, H_c \quad (1)$$

Where X = five years average equivalent doses for each group per radiation worker (mSv), H_c = five years summation of doses for each group per radiation worker. The five years average equivalent doses for each type per radiation worker such as physicians, physicists, radiologists, assistants of radiologists, nurses, assistants of nurses and nurse aids are defined as:

$$Y = (1/5).\, H_t \quad (2)$$

Where Y = five years average equivalent doses for each type per radiation worker (mSv), H_t = five years summation of doses for each type per radiation worker.

The five years average collective equivalent doses for the radiation workers can be calculated using Equation (3)

$$Z = M \times H \quad (3)$$

Where Z = five years average collective equivalent dose for the radiation workers. The unit of average collective equivalent dose is called man Sv. M = Number of radiation workers and H = average equivalent dose per a radiation worker (Sv).

The fatal cancer risk for the radiation workers were calculated by Equation (4).

$$R = \text{Coeff.} \times Z \quad (4)$$

Where R = the fatal cancer risk for the radiation works, Coeff. = the nominal probability coefficients for stochastic effects (probability per unit effective dose) = 4 % Sv^{-1} = 0.04 Sv^{-1}.

Z = five years average collective equivalent dose for the radiation workers[6,8]. Analyses were performed using computer.

Results

Table 1 describes the distribution of radiation workers monitored according to the groups for the 2004-

2008 periods. The Radiology Department at Phramongkutklao Hospital composed of 3 departments such as diagnosis 54 persons, radiotherapy 18 persons and nuclear medicine 16 persons that the radiation workers of each department were classified for 3 groups. The first group was Physician, the second group was Physicist, Technologist and Assistant technologist and the last group was Nurse, Assistant of nurse and Nurse Aids. The average number of Physicists, technologists and assistants of technologists for all occupational groups was 45 persons from the average total of radiation workers in this period 88 persons (51.13%) that is the most numerous occupational group. Nurse, assistant of nurse and nurse aids, the average number of them was 20 persons (22.73%; 20/88).

The result of average annual equivalent dose of occupational groups in the years 2004-2008 are presented in Table 2, about 59.73 % of radiation workers in the Radiology Department at Phramongkutklao Hospital received an annual average equivalent dose below 0.02 mSv high defined as recording level and no radiation workers received doses above the ICRP Publication 60 recommended dose limit (20 mSv per year). Table 3 shows the five years average equivalent dose per radiation worker during 2004-2008 was 1.098 mSv.

Of all occupational groups measured diagnosis group received the highest five years average equivalent dose, collective equivalent dose and had highest fatal cancer risk (Table 4). The five years

Table 1. Distribution of number of radiation workers by occupational groups (2004-2008)

Occupational groups	Number of Radiation Workers					
	2004	2005	2006	2007	2008	Average
Diagnosis						
Physician	12	12	21	20	26	18
Physicist, Technologist & Assistant technologist	36	36	23	27	27	30
Nurse, Assistant of nurse & Nurse Aids	7	6	6	6	7	6
Radiotherapy						
Physician	6	2	2	1	2	2
Physicist, Technologist & Assistant technologist	6	7	7	7	7	7
Nurse, Assistant of nurse & Nurse Aids	10	9	9	8	9	9
Nuclear Medicine						
Physician	3	3	4	3	3	3
Physicist, Technologist & Assistant technologist	6	7	9	8	8	8
Nurse, Assistant of nurse & Nurse Aids	6	2	3	2	11	5
Total	92	84	84	82	100	88

Table 2. Distribution of annual equivalent dose to radiation workers during 2004-2008

Dose range (mSv)	Number of Radiation Workers n (%)					
	2004	2005	2006	2007	2008	Average n (%)
< 0.02	60 (65.22)	50 (59.52)	49 (58.33)	50 (60.98)	55 (55)	52.80 (59.86)
0.02-0.09	1 (1.09)	1 (1.19)	1 (1.19)	2 (2.44)	1 (1)	1.20 (1.36)
0.10-0.99	28 (30.43)	32 (38.10)	34 (40.48)	30 (36.59)	36 (36)	32.00 (36.24)
1.00-4.99	2 (2.17)	1 (1.19)	0	0	7 (7)	2.00 (2.5)
5.00-9.99	1 (1.09)	0	0	0	1 (1)	0.40 (0.45)
10.00-14.99	0	0	0	0	0	0
15.00-19.99	0	0	0	0	0	0
20.004	0	0	0	0	0	0
Total	92	84	84	82	100	88

Number in parentheses was percent

average equivalent dose, collective equivalent dose and fatal cancer risk for physicist; technologist and assistant of technologist were the highest (Table 5). Total risk per the whole radiation workers was 3.86 x 10^{-3} to the five years average equivalent dose of 4.569 mSv. Table 6 shows occupational exposure dose from medical uses of radiation in other countries

Discussion

In the Radiology Department at Phramongkutklao Hospital, occupationally exposed workers are monitored by the Division of Radiation Protection Services, Department of Medical Sciences which measures radiation exposures and evaluated doses from external exposures. All radiation workers are routinely issued individual monitoring devices.

The average annual dose received by the diagnosis group during 2004-2008 was 0.524 mSv per radiation worker, which was the lowest among the three groups. The highest individual annual dose in these groups was 2.245 mSv (Nuclear medicine group). When the monitoring radiation workers were classified into three occupational classifications, classification of physicist, technologist and assistant of technologist received the highest five years average annual doses, the lowest was classification of physician. This effect may be partially explained that physicist, technologist and assistant of technologist were the radiation workers who practiced directly with radiology instruments.

The five years average collective equivalent dose and fatal cancer risk for the physicist, technologist and assistant of technologist were the highest and lowest in physician among radiation workers, but did not exceed dose limit that (ICRP) Publication 60 recommended. So, the radiation workers in the

Table 3. The annual average equivalent dose per radiation worker for occupational groups during 2004-2008

Year	Occupational groups		
	Diagnosis (1)	Radiotherapy (2)	Nuclear Medicine (3)
2004	0.321	1.800	2.245
2005	0.451	1.800	1.906
2006	0.397	1.800	2.585
2007	0.553	1.801	2.284
2008	0.898	1.800	2.204
Total 5 years	2.620	9.001	11.224
Average per year	0.524	1.800	2.245
Equivalent dose of whole radiation worker = Average per year x M*	28.292 (0.524 x 54)	32.403 (1.800 x 18)	35.918 (2.245 x 16)

Average dose per radiation worker = [(1) + (2) + (3)]/Number of radiation workers = 96.612/88 = 1.098 mSv

M* is Number of each occupational radiation workers

Table 4. The five years average equivalent dose per radiation worker, collective equivalent dose and fatal cancer risk for occupational groups

Occupational groups	Average equivalent dose/worker (mSv) (1) = X = 1/5(Hc)	Collective equivalent dose (man Sv) (2) = Z = (1)x M	Fatal cancer risk (3) = R = Coeff x (2)
Diagnosis	0.524	0.028 ($0.524 \times 10^{-3} \times 54$)	1.11×10^{-3}
Radiotherapy	1.800	0.032 ($1.8 \times 10^{-3} \times 18$)	1.33×10^{-3}
Nuclear Medicine	2.245	0.036 ($2.245 \times 10^{-3} \times 16$)	1.44×10^{-3}
Total	4.569	0.096	3.86×10^{-3}

Hc is five years summation of doses for each group per radiation worker; M = Number of radiation workers; Coeff is the nominal probability coefficients for stochastic effects (probability per unit effective dose) = 4% Sv^{-1}

Table 5. The five years average equivalent dose per radiation worker, collective equivalent dose and fatal cancer risk for occupational classification

Occupation	Average equivalent dose/worker (mSv) (1) = X = 1/5(Ht)	Collective equivalent dose (man Sv)(2) = Z = (1)x M	Fatal cancer risk (3) = R = Coeff x (2)
Physician	0.472	0.011	4.34×10^{-4}
Physicist, Technologist & Assistant technologist	1.493	0.067	2.69×10^{-3}
Nurse, Assistant of nurse & Nurse Aids	0.881	0.018	7.05×10^{-4}
Total	2.846	0.096	3.83×10^{-5}

Ht is five years summation of doses for each type per radiation worker; M = Number of radiation workers; Coeff is the nominal probability coefficients for stochastic effects (probability per unit effective dose) = 4% Sv^{-1}

Table 6. Show exposures to work from medical uses of radiation (Data from UNSCEAR Survey of Occupational Exposures unless otherwise indicated)[13]

Country (1985-1989)	Average annual effective dose (mSv)		
	Diagnosis	Radiotherapy	Nuclear Medicine
Australia	0.059	0.34	0.16
China	1.84	1.39	1.57
German	0.083	0.66	0.51
India	0.34	0.95	0.85
Indonesia	1.67	1.55	1.20
Spain	0.76	0.86	1.74

Radiology Department at Phramongkutklao Hospital have safety for working.

Comparison with other studies

The five years average annual doses of nuclear medicine and radiotherapy radiation workers in the Radiology Department at Phramongkutklao Hospital was higher than some countries. This effect may be a very small number of radiation workers in the present study and differences in placement of dosimeters badge, type of dosimeter.

Plans for the future

Recommendation, the authors would like to study in association of placement of individual dosimeters (film badge), percentage of using, the knowledge of radiation workers about radiation workers, equipment and environment management with fatal cancer risk of radiation workers in Army hospitals. Moreover, Cost effectiveness of equipment management for prevention of radiation-induced fatal cancer risk will be the interesting topic too.

The placement of individual dosimeters is important to accuracy of measurement. The Radiation Protection Board recommends that in general personal dosimeters should be placed high on the frontal part of the trunk; and in special situations in medical radiology where protective clothing such as lead aprons are worn, which provide significant attenuation of the incident radiation on some parts of the body, two dosimeters, one over and the other under the lead apron may be used. However, if a single dosimeter is used, it should be worn outside the lead apron, usually high on the trunk[14].

Conclusion

The overall five years average collective equivalent dose and fatal cancer risk for nuclear medicine group was the highest. Due to the result that the five years average equivalent dose was 1.098 mSv per radiation worker, the total risk per the whole monitored radiation workers were 3.86×10^{-3}. This value

was estimated from a very small number of radiation workers.

Acknowledgements

The authors wish to thank Asst. Prof. Wiroj Jiamjarasrangsi from the Department of Preventive & Social Medicine Faculty of Medicine Chulalongkorn University and Mr. Attakovit Sa-nguenu-sat from Division of Radiation Protection Services, Department of Medical Sciences for their help and advice in this study.

Potential conflicts of interest

Phramongkutklao Hospital's Foundation under Her Royal Highness Princess Maha Chakri Sirindhorn's Patronage.

References

1. Drexler G, Panzer W. Occupational exposure in x-ray diagnosis. Radiat Prot Dosimetry 1990; 32: 163-9.
2. Court Brown WM, Doll R. Expectation of life and mortality from cancer among British radiologists. Br Med J 1958; 2: 181-7.
3. Matanoski GM, Seltser R, Sartwell PE, Diamond EL, Elliott EA. The current mortality rates of radiologists and other physician specialists: deaths from all causes and from cancer. Am J Epidemiol 1975; 101: 188-98.
4. Seltser R, Sartwell PE. The influence of occupational exposure on the mortality of American radiologist and other medical specialists. Am J Epidemiol 1965; 81: 2-22.
5. Smith PG, Doll R. Mortality from cancer and all causes among British radiologists. Br J Radiol 1981; 54: 187-94.
6. The International Commission on Radiological Protection. ICRP Publication 60: 1990 Recommendations of the International Commission on Radiological Protection ICRP. New York: Pregamon Press; 1991: 16, 44-6.
7. International Atomic Energy Agency. Health surveillance of persons occupationally exposed to jonizing radiation: guidance for occupational physicians. Vienna: IAEA; 1998: 28.
8. The International Commission on Radiological Protection. ICRP Plublication 73: Radiological protection and safety in medicine. Great Britain: BPC Wheatons; 1996: 6-8, 36-7.
9. Litodo ML, Cavallini A, Chili L. Local recording practice in dose record keeping in Italy. Radiat Prot Dosimetry 1994; 54: 372.
10. Pan ZQ. Radiation exposures caused by the nuclear industry in China. Radiat Prot Dosimetry 1995; 62: 245-54.
11. McEwan AC. Occupational radiation exposure in New Zealand. Radiat Prot Dosimetry 1988; 22: 243-51.
12. Wohni T, Backe S. Occupational radiation doses in Norway 1981-1983. Radiat Prot Dosimetry 1985; 12: 297-302.
13. United Nations Scientific Committee on the Effects of Atomic Radiation. Effects and risks of ionizing radiation. New York: United Nation; 1993: 493-500.
14. Osei EK. Occupational Radiation Exposure in Ghana. Radiat Prot Dosimetry 1997; 71: 207-14.

ปริมาณรังสีสมมูลรายกลุ่มเฉลี่ยและความเสี่ยงที่เป็นอันตรายต่อการเกิดมะเร็งสำหรับบุคลากรทางรังสี ในกองรังสีกรรมที่โรงพยาบาลพระมงกุฎเกล้า ระหว่างปี พ.ศ. 2547-2551

ศุภขจี แสงเรืองอ่อน, มานัส มงคลสุข, ธรรม์พงษ์ รังสิภัทร์

วัตถุประสงค์: *เพื่อประเมินปริมาณรังสีสมมูลเฉลี่ย 5 ปี, ปริมาณรังสีสมมูลรายกลุ่มเฉลี่ย และความเสี่ยงของการเกิดมะเร็งสำหรับบุคลากรทางรังสีในกองรังสีกรรม ที่โรงพยาบาลพระมงกุฎเกล้า*

วัสดุและวิธีการ: *บุคลากรทางรังสีของกองรังสีกรรม โรงพยาบาลพระมงกุฎเกล้าได้รับการประเมินปริมาณรังสีที่ได้รับจากการทำงานทางรังสี โดยการใช้เครื่องวัดรังสีประจำตัวบุคคลแบบฟิล์ม และทำการวิเคราะห์ปริมาณรังสีที่ได้รับโดยกรมวิทยาศาสตร์การแพทย์ โดยการศึกษานี้เป็นการสำรวจปริมาณรังสีที่บุคลากรทางรังสีในกองรังสีกรรมที่โรงพยาบาลพระมงกุฎเกล้าที่ได้รับย้อนหลังในปี พ.ศ. 2547-2551*

ผลการศึกษา: *การกระจายของบุคลากรทางรังสีในปี พ.ศ. 2547-2551 พบว่าส่วนใหญ่เป็นกลุ่มของนักฟิสิกส์, เทคนิเชี่ยน และผู้ช่วยเทคนิเชี่ยน (51.13%) มีพยาบาล, ผู้ช่วยพยาบาลและพนักงานผู้ช่วยการพยาบาล 22.73% ประมาณ 59.73% ของบุคลากรทางรังสีได้รับรังสีสมมูลเฉลี่ยประจำปีต่ำกว่า 0.02 มิลลิซีเวิร์ต และไม่มีบุคคลากรทางรังสีที่ได้รับ ปริมาณรังสีมากกว่าขีดจำกัดปริมาณรังสีที่แนะนำ โดยคณะกรรมาธิการนานาชาติว่าด้วยการป้องกันอันตรายจากรังสี (20 มิลลิซีเวิร์ตต่อปี) โดยปริมาณรังสีสมมูลเฉลี่ย 5 ปี ต่อบุคลากรทางรังสี 1 คนเท่ากับ 1.098 มิลลิซีเวิร์ต โดยกลุ่มงานเวชศาสตร์นิวเคลียร์ได้รับปริมาณรังสีสมมูลเฉลี่ย 5 ปี, ปริมาณรังสีสมมูลรายกลุ่มเฉลี่ยและความเสี่ยงของการเกิดมะเร็งสูงสุด โดยนักฟิสิกส์, เทคนิเชี่ยน และผู้ช่วยเทคนิเชี่ยนได้รับปริมาณรังสีสมมูลเฉลี่ย 5 ปี, ปริมาณรังสีสมมูลรายกลุ่มเฉลี่ย และความเสี่ยงของการเกิดมะเร็งสูงสุด*

สรุป: *ความเสี่ยงของการเกิดมะเร็งต่อบุคลากรทางรังสีทั้งหมดคือ 3.86×10^{-3} เนื่องจากได้รับรังสีสมมูลรายกลุ่มเฉลี่ย 5 ปี เท่ากับ 0.096 ซีเวิร์ต-คน ค่าเหล่านี้ได้รับการประมาณจากกลุ่มบุคลากรจำนวนน้อย ดังนั้นในการศึกษาต่อไปจะทำการศึกษาในกลุ่มประชากรที่จำนวนมากขึ้น*