UNIVERSITI SAINS MALAYSIA

Research Title

RADIATION EXPOSURE TO SURGEON DURING SELECTED ORTHOPAEDIC PROCEDURES UNDER FLUOROSCOPIC GUIDANCE TECHNIQUE

Author

Dr. Tengku Muzaffar Tengku Mohamed Shihabudin

Co-author

Assoc. Prof. Dr Ahmad Zakaria

Dr Iskandar Mohd Amin

Acknowledgement

This study was supported by the university short term grant (No.304/PPSP/6131259) and was approved by the University Research and Ethic Committee.

BAHAGIAN PENYELIDIKAN & PEMBANGUNAN
CANSELORI
UNIVERSITI SAINS MALAYSIA

Laporan Akhir Projek Penyelidikan Jangka Pendek

1) Nama Penyelidik:

Dr Tengku Muzaffar Tengku Mohd Shihabudin

Nama Penyelidik-Penyelidik
Lain (Jika berkaitan) :

i) Prof. Madya Dr Ahmad Zakaria
ii) Dr Iskandar Mohd Amin

2) Pusat Pengajian/Pusat/Unit :

Pusat Pengajian Sains Perubatan Universiti Sains Malaysia

3) Tajuk Projek:

Radiation exposure to surgeon during selected orthopaedic procedures under fluoroscopic guidance technique.

4) (a) Penemuan Projek/Abstrak
(Perlu disediakan makluman di antara 100 – 200 perkataan di dalam Bahasa Malaysia dan Bahasa Inggeris. Ini kemudiannya akan dimuatkan ke dalam Laporan Tahunan Bahagian Penyelidikan & Pembangunan sebagai satu cara untuk menyampaikan dapatan projek tuan/puan kepada pihak Universiti).

Abstrak dalam Bahasa Malaysia:-

Bilangan kaedah pembedahan otopedik yang menggunakan bantuan paparan imej fluoroscopi (image intensification fluoroscopy) telah meningkat dengan banyaknya sejak beberapa tahun yang lepas. Terdapat kesangsian tentang kemungkinan adanya kesan buruk radiasi. Dalam kajian ini, pantulan rawak radiasi ke mata, tangan dan leher doktor bedah telah diukur semasa pembedahan memasukkan implant ke tulang peha yang dijalankan dengan bantuan mesin fluoroscopi. Dosimeter thermoluminescent telah digunakan untuk mengukur kuantiti dose radiasi yang diterima oleh doktor bedah semasa atucara tersebut.

Purata masa pendedahan radiasi atau masa di mana fluoroscopi digunakan semasa kaedah pembedahan tulang peha 'interlocking nail' dan 'dynamic hip screw' adalah 3.89 minit dan 3.03 minit. Kajian menunjukkan doctor bedah telah menerima sejumlah kesan pantulan rawak radiasi semasa pembedahan tersebut. Tangan menerima kesan pantulan rawak radiasi yang tertinggi diukuti oleh mata dan leher. Kesan pantulan rawak radiasi ini adalah rendah. Analisis data dari kajian ini, dianggarkan kemungkinan adalah amat rendah untuk seseorang doctor bedah untuk menerima lebih dari had maksimun dose radiasi tahunan yang dibenarkan sebagaimana yang telah ditetapkan oleh badan antarabangsa.

Abstrak dalam Bahasa Inggeris:-

The number of orthopaedic surgical procedures using image intensification fluoroscopic assistance had increased markedly over the past few years. There are growing concerns over possible associated radiation health hazards. In this study, scattered radiation to the eye, hand and neck of the primary surgeon were measured during interlocking nail of femur and dynamic hip screw fixation assisted by the fluoroscopic machine. Thermoluminescent dosimeter was used to quantify the radiation dose received by the surgeon.

Mean radiation exposure time or duration that fluoroscopy was used during the procedure for interlocking nail of femur and dynamic hip screw fixation were 3.89 minutes and 3.03 minutes respectively. Study showed that the primary surgeon received certain amount of scattered

radiation dose during the procedures. The hand received the highest scattered dose followed by the eye and neck. The scattered dose was small. By extrapolating these results, it is unlikely for an individual surgeon to receive more than the recommended annual dose limit as set by the international organization.

(b) Senaraikan Kata Kunci yang digunakan di dalam abstrak:

Bahasa Malaysia	Bahasa Inggeris
Radiasi	Radiation
Pendedahan	Exposure
Fluoroscopi	Fluoroscopy
Doktor bedah	Surgeon

5) Output Dan Faedah Projek

(a) Penerbitan (termasuk laporan/kertas seminar)
(Sila nyatakan jenis, tajuk, pengarang, tahun terbitan dan di mana telah diterbit/dibentangkan).

Kajian ini telah di hantar untuk dipertimbangkan untuk penerbitan dalam ' The Medical Journal of Malaysia – Orthopaedic Supplement'.

(b) Faedah-Faedah Lain Seperti Perkembangan Produk, Prospek Komersialisasi Dan Pendaftaran Paten.
(Jika ada dan jika perlu, sila guna kertas berasingan)

Faedah lain yang berguna adalah kajian ini telah memberi pengetahuan tentang tahap radiasi yang sebenarnya wujud dalam atucara pembedahan tersebut adalah rendah dan selamat. Secara tidak langsung kajian ini membuktikan pihak hospital Universiti Sains Malaysia tidak perlu berbelanja lebih kerana tahap keselamatan yang ada sekarang adalah baik.

(c) Latihan Gunatenaga Manusia

i) Pelajar Siswazah: ....

....

....

....

ii) Pelajar Prasiswazah: ....

....

....

....

iii) Lain-Lain : ....

....

....

....

6. Peralatan Yang Telah Dibeli:

Cip Termoluminescent Dosimetri (TLD)

UNTUK KEGUNAAN JAWATANKUASA PENYELIDIKAN UNIVERSITI

Kurang 'output' dari segi penulisan/penerbitan k/kerja

T/TANGAN PENGERUSI
J/K PENYELIDIKAN
PUSAT PENGAJIAN

PROFESSOR ABDUL AZIZ BABA
Chairman of Research & Ethics Committee
School of Medical Sciences
Health Campus
Universiti Sains Malaysia
16150 Kubang Kerian, Kelantan

5/6/..

UNIVERSITI SAINS MALAYSIA
JABATAN BENDAHARI
KUMPULAN WANG PENYELIDIKAN GERAN USM(304)
PENYATA PERBELANJAAN SEHINGGA 30 JUN 2005

Jumlah Geran:	RM	11,130.00		Ketua Projek:	DR.TG MUZAFFAR TG.MD.SHIHABUDIN
Peruntukan 2003				Tajuk Projek:	Radiation Exposure to Surgeons During Selected Orthopaedic ProceduresUnder Fluoroscopic Guidance Technique
(Tahun 1)	RM	0.00			
Peruntukan 2004					
(Tahun 2)	RM	0.00			
Peruntukan 2005				Tempoh:	01 Januari 03 - 31 Disember 04
(Tahun 3)	RM	0.00		No.Akaun:	304/PPSP/6131259

Kwg	Akaun	PTJ	Projek	Donor	Peruntukan Projek	Perbelanjaan Tkumpul Hingga Tahun Lalu	Peruntukan Semasa	Tanggungan Semasa	Bayaran Tahun Semasa	Belanja Tahun Semasa	Baki Projek
304	11000	PPSP	6131259		-	-	-	-	-	-	-
304	14000	PPSP	6131259		-	-	-	-	-	-	-
304	15000	PPSP	6131259		-	-	-	-	-	-	-
304	21000	PPSP	6131259		2,950.00	1,993.50	956.50	-		-	956.50
304	22000	PPSP	6131259		440.00	-	440.00	-	-	-	440.00
304	23000	PPSP	6131259		300.00	-	300.00	-	-	-	300.00
304	24000	PPSP	6131259		-	-	-	-	-	-	-
304	25000	PPSP	6131259		-	-	-	-	-	-	-
304	26000	PPSP	6131259		-	-	-	-	-	-	-
304	27000	PPSP	6131259		3.100.00	3,196.55	(96.55)	-		-	(96.55)
304	28000	PPSP	6131259		-	-	-	-	-	-	-
304	29000	PPSP	6131259		4,340.00	600.00	3,740.00	-		-	3.740.00
304	32000	PPSP	6131259		-	-	-	-	-	-	-
304	35000	PPSP	6131259		-	-	-	-	-	-	-
					11,130.00	5,790.05	5,339.95	-	-	-	5,339.95

DECLARATION BY THE AUTHORS

In consideration of the expenses of editing and publishing and the professional benefits relating to publication of this work, we the undersigned hereby transfer to the **Malaysian Medical Journal** all rights, titles and interest to all parts of the written work named below including:

1. Copyright
2. The right to grant permission to republish the article for sale or free distribution.
3. The right to produce reprints for sale or free distribution
4. The right to republish the work in a collection of article or in any other format

In addition, we affirm that this work is original and the facts presented are to the best of our knowledge accurate and true, that this work has not been previously published, is not subject to copyright or other rights except our own to be transferred to the Journal, and has not otherwise been submitted for publication except under circumstances communicated to the journal in writing at the time the work was first submitted.

TITLE OF ARTICLE

Radiation Exposure To The Surgeon During Femoral Interlocking

Nailing Under Fluoroscopic Imaging.

Name of author	Signature	Date
S Muzafar		
Y Imran		
MA Iskandar		
A Zakaria		

Radiation Exposure To The Surgeon During Femoral Interlocking Nailing Under Fluoroscopic Imaging.

*S Muzaffar, *Y Imran , *MA Iskandar , +A Zakaria,

*Lecturer
Department of Orthopaedics, School of Medical Science USM
16150 Kubang Kerian, Kelantan Malaysia

+ Assoc Professor and Lecturer
Department of Nuclear Medicine, School of Medical Science USM
16150 Kubang Kerian, Kelantan Malaysia.

Correspondence to:
Dr Tengku Muzaffar
Tel: 09-7663000 ext. 4503 @ 019-9614404
Fax: Fax : 609-7653370
Email: tgmuz@streamyx.com

Acknowledgement

This study is supported by the university short term grant (No.304/PPSP/6131259) and approved by the University Research and Ethic Committee.

Radiation Exposure To The Surgeon During Femoral Interlocking Nailing Under Fluoroscopic Imaging.

Abstracts

Femoral interlocking nailing requires fluoroscopic assistance for the insertion of nail and distal screw. In this study, scattered radiation to the eye and hand of the operating surgeon were measured during interlocking nailing of the femur using fluoroscopic imaging. Thermo luminescent dosimeter (TLD) was used to quantify the dose received by the surgeon.

The mean radiation exposure time during the procedure was 3.89 minutes. Mean scattered radiation dose to the hand and eye were 0.27 mSv per procedure and 0.09 mSv per procedure respectively. These very low doses have made a surgeon very unlikely to receive more than the recommended annual dose limit set by the National Council on Radiological Protection.

Keywords: Radiation, exposure, interlocking nailing, femur

Introduction

Interlocking intramedullary nailing remained as the most widely used procedure for fractured femur fixation because of its biological and mechanical advantages. The procedure requires fluoroscopic assistance for the insertion of nail and screw. As this machine releases ionizing radiation, surgeon should be aware of the scattered radiation during the surgery [(1)]. Although the hands tend to be in closed proximity to the x-ray beam during distal screw insertion, surgeon rarely wears the protective glove, as it is cumbersome. Wearing the lead goggle to protect the eyes is also not commonly practice by the surgeon.

The purpose of this study was to measure the scattered radiation dose to the hands and eyes of the operating surgeon during interlocking intramedullary nailing of the femur, a common procedure for all orthopedic surgeons. The finding will enable us to predict how many procedures are required before annual dose limit is exceeded.

Materials and methods

This is a prospective study of ten consecutive patients who were admitted to Hospital USM in 2003 sustained close fracture of the femur who required internal fixation using interlocking nail.

The scattered radiation dose to the hands and eyes of the operating surgeon during the procedure under the fluoroscopic assistance were quantified. The duration of fluoroscopic exposure (duration of radiation exposure) during the procedures were measured directly from the reading recorded by the fluoroscopic machine. (Siemens Siremobil Compact, model 1173355, Germany)

Scattered dose to the surgeon were quantified using a Lithium Fluoride thermo luminescent dosimeter chip (TLD). It has a minimum detectable dose of 10μSv. The devices were prepared and calibrated in the Secondary Standard Dosimeter Lab (SSDL) in Malaysian Institute For Nuclear Technology (MINT) before they were used in the study. After each procedure the TLD chips were analyzed in SSDL to measure the scattered dose detected by the chips.

i. Placement of the TLD.

The radiation doses to the eyes were measured by two TLDs placed at the upper part of the surgical mask, each one below the eye. TLD rings were used to measure the radiation doses to the hands. The rings were worn over the middle and index finger of both right and left hands and each ring had one TLD chip attached. The TLD rings were sterilized using ethylene oxide. At the end of the procedures, the TLD chips were sent to MINT for analysis.

ii. Fracture fixation

There were few surgeons involved in the procedures and they were the treating surgeons of the patients. Their surgical experience ranged from 4 to 7 years. The fracture fixation followed the standard surgical technique. One proximal and two distal locking screws were inserted in all cases. All the procedures were performed with the patient lying supine on the fracture table. The C-arm of the image intensifier fluoroscopy was positioned between the patient's lower limbs therefore the radiation beam remained perpendicular to the limb for both anteroposterior and lateral views.

Results

The radiation exposure time is the duration where fluoroscopy is used during each of the procedure. The mean radiation exposure time per procedure was 3.89 minutes. The median, maximum and minimum exposure times were 3.71 minutes, 6.15 minutes and 1.3 minutes respectively. The kVp of the x-ray tube in this study ranges from 57 kVp until 75 kVp.

The duration of radiation exposure for the patients underwent interlocking nail and the mean scattered radiation dose to the eye and hand for each patient are shown in table 1 and table 2. Table 3 shows the mean, median, maximum and minimum for scattered radiation dose to eye and hand

It is also observed that the scattered radiation dose to eye and hand increases with longer duration of exposure as shown by scattered plot graphs in figure 1 and figure 2.

Discussion

Scattered radiation dose to the hand and eye absorbed by the TLD in that region was directly proportional to the duration of exposure ($p<0.005$ and $p<0.05$ respectively). As the period of image intensification usage become prolong, the scattered radiation dose increases as shown in figure 1 and 2.

This study showed that the mean scattered radiation dose to the hand was higher as compared to eye. This finding was not surprising as the hands tend to be closer to the radiation beam especially during distal screw insertion[(2)]. The results were supported by other study done by Noorden et al [(3)]. Greater level of scattered radiation was recorded during the femoral nailing procedures that include distal locking nail insertion. [(4)]

Mean scattered radiation dose to the eye was 0.09 mSv per procedure or 0.02 mSv per minute of radiation exposure. The annual dose limit to the eye lens recommended by National Council on Radiation Protection was 150 mSv.[(5,6)] Therefore a surgeon have to perform 1,666 similar procedure or a total duration of 7,500 minute of exposure in a year to reach the dose limit. This implies that under normal circumstances, the dose is unlikely to be hazardous to the surgeon's eye lens.

Mean scattered radiation dose to the hand during the procedure was 0.27 mSv per procedure or 0.07 mSv per minute. The radiation exposure was still far from the recommended annual dose limit to the hand which is 500 mSv.[(5,6)] A total radiation exposure of 119 hours or 1850 similar procedures need to be performed in a year to reach the limit.

Table 4 summarize the minimal number of femoral interlocking nailing to reach recommended annual dose limit to the eye and hand as recommended by the National Council on Radiation Protection.

From the observations, this study suggests that a surgeon is able to perform 1,666 interlocking nailing of the femur in a year or 4.5 femur fixation everyday in a year safely, considering the overall radiation exposures to the hands and eyes. This is extremely large number of procedures considering that in Hospital Kota Bharu there were not more than seventy procedures of femoral interlocking nail done throughout the year 2004. Furthermore these seventy procedures were performed by many surgeons in that center.

Based on these observations, scattered radiation to the hand and eye during femoral interlocking nail under fluoroscopic imaging is very minimal and unlikely to exceed the annual dose limit. Many other studies had concluded that radiation exposure to the surgeons was low . [2,7]

Conclusion

The orthopedic surgeon is consistently exposed to scattered radiation during interlocking nailing of the femur under fluoroscopic imaging. This study indicates that scattered radiation dose to the hand and eye of the operating surgeon during interlocking nail of the femur under fluoroscopic imaging was low. It requires a large number of procedures in a year in order to exceed the annual dose limit to the eye and hand as set by the National Council on Radiological Protection.

Acknowledgement

We would like to thank Assoc. Prof. AS Devnani, from the Dept. of Orthopaedics, School of Medical Sciences, USM for his continuous support for this study.

Referrences

1. Hynes DE, Conere T, Mee MB, Cashman WF. Ionizing radiation and orthopaedic surgeon. J Bone Joint Surg 1992:74-B: 332-334.

2. Goldstone KE, Wright IH, Cohen B. Radiation exposure to the hands of orthopaedic surgeons during procedures under fluoroscopic x-ray control. Br J Radiol 1993: 66: 899-901.

3. Noordeen MH, Shergil N, Twyman RS, Cobb JP, Brigges T. Hazard of ionizing radiation to trauma surgeon. Injury 1993: 24-8: 562-564.

4. Sanders R, Koval KJ, Dipasquale T, Schmelling G, Stenzler S, Ross E. Exposure of the orthopaedic surgeon to radiation. J Bone Joint Surg 1993: 75-A: 326-330.

5. Dowd SB. Practical Radiation Protection And Applied Radiobiology. W.B Saunders, 1994:140.

6. Atomic Energy Licensing Act 1984. Radiation Protection (Basic Safety Standards) Regulations 1988.

7. Levin PE, Schoen RW, Browner BD. Radiation exposure to the surgeon during closed Interlocking intramedulary nailing. J Bone Joint Surg 1987 : 69-A: 761-766.

Tables

Table 1: Radiation exposure time during interlocking nail of the femur and the scattered dose to hand

Patient/ Procedure	Radiation Exposure (minute)	Scattered Radiation Dose to hand (mSv) (mSv)
1	2.86	0.21
2	6.15	0.36
3	1.3	0.11
4	2.1	0.19
5	6.15	0.38
6	4.2	0.38
7	3.22	0.28
8	5.33	0.23
9	5.43	0.44
10	2.38	0.14

r = 0.828, R square = 0.685, p = 0.003

Table 2: Radiation exposure time during interlocking nail of the femur and the scattered dose to eye

Patient/ Procedure	Radiation Exposure (minute)	Scattered Radiation Dose to eye (mSv)
1	2.86	0.12
2	6.15	0.18
3	1.3	0.06
4	2.1	0.03
5	6.15	0.12
6	4.2	0.14
7	3.22	0.05
8	5.33	0.08
9	5.43	0.08
10	2.38	0.02

r = 0.653, R = 0.426, p = 0.041

Table 3: Mean, median, maximum and minimum of the scattered radiation dose to the eye and hand.

	Scattered radiation dose (mSv per procedure) eye	hand
mean (sd)	0.09(0.05)	0.27(0.11)
median (IQR)	0.08(0.04)	0.26(0.18)
max.	0.18	0.44
min	0.02	0.11

Table 4: Minimum number of procedures needed to reach the recommended annual dose limit to the eye and hand

	Scaterred dose per-procedure (mSv)	Recommended annual dose limit (mSv)	Number of procedures needed to reach annual dose limit
Eye	0.09	150	1, 666
Hand	0.27	500	1,850

Figures

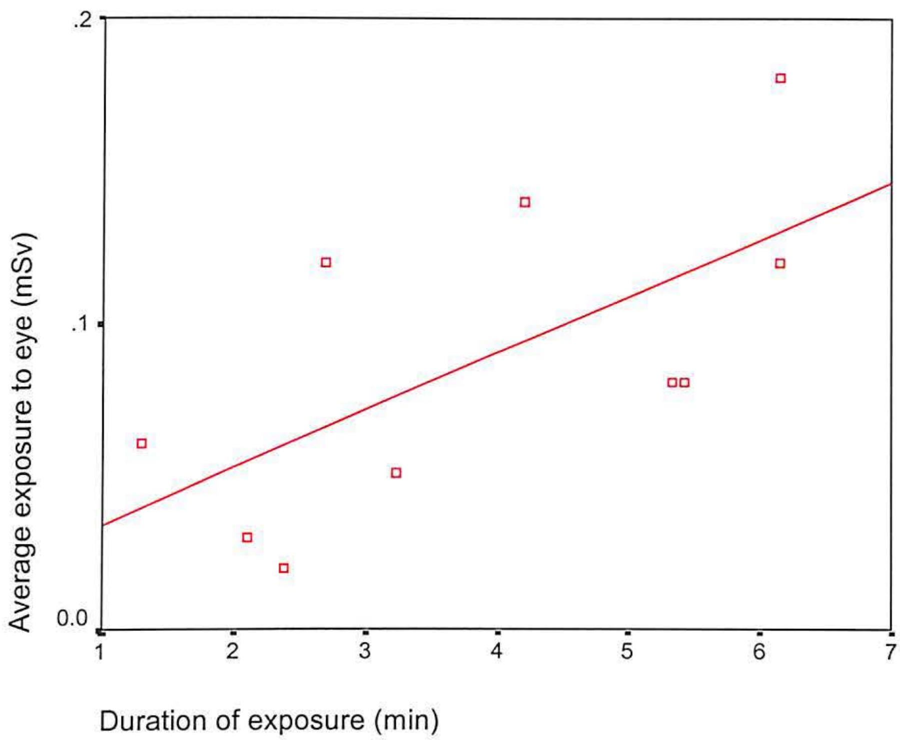

Figure 1: Scaterred plot graph showing mean scattered radiation exposure to eye (mSv) vs duration of exposure (min)

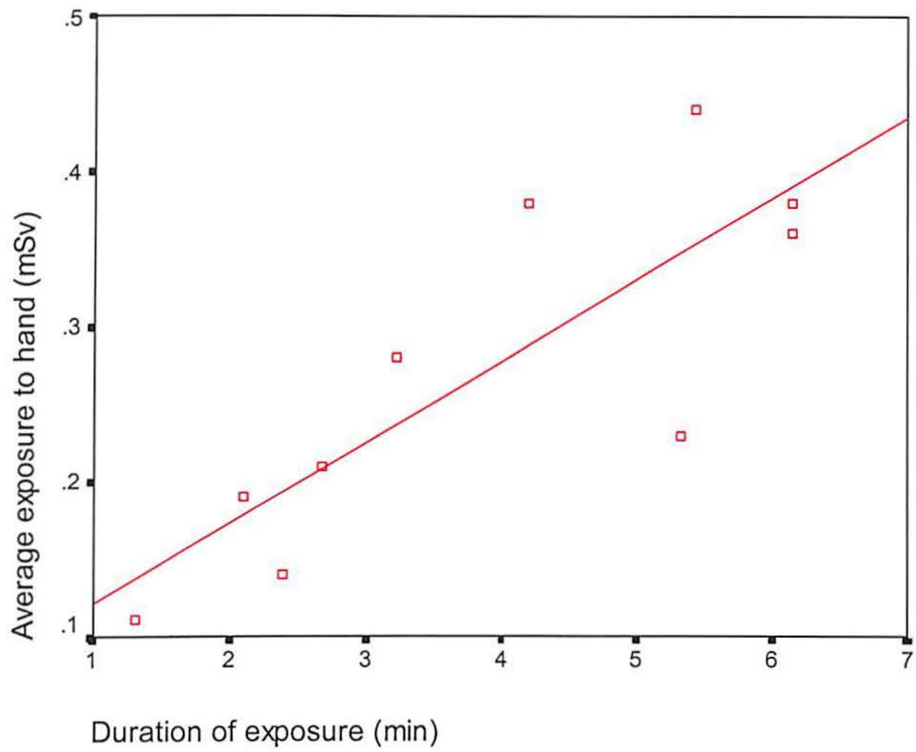

Figure 2: Scattered plot graph showing mean radiation exposure to hand (mSv) vs duration of exposure (min)

UNIVERSITI SAINS MALAYSIA

Research Title

RADIATION EXPOSURE TO SURGEON DURING SELECTED ORTHOPAEDIC PROCEDURES UNDER FLUOROSCOPIC GUIDANCE TECHNIQUE

Author

Dr. Tengku Muzaffar Tengku Mohamed Shihabudin

Co-author

Assoc. Prof. Dr Ahmad Zakaria

Dr Iskandar Mohd Amin

Acknowledgement

This study was supported by the university short term grant (No.304/PPSP/6131259) and was approved by the University Research and Ethic Committee.

Table of Contents

DEFINITION OF TERMS

absorbed dose: the amount of energy transferred from ionizing radiation to an irradiated object per unit mass. This absorbed energy is responsible for whatever biological damage occurs as a result of tissue being exposed to x-radiation.

absorbed dose equivalent: the product obtained by multiplying the absorbed dose times the quality factor. This quantity considers the biological effects of various types of radiation to humans.

anneal: part of the reading process of the thermoluminescent dosimeter where high temprature is applied to ensure all electrons have been removed from the electrons traps.

awl: an instrument used to gain entry site at the piriform fossa of a femur.

carcinogenic: any substance which causes cancer.

C-arm fluoroscope: a portable device for producing real-time image of a patient. The opposite ends of the 'c'-shaped support arm hold the X-ray tube and the image intensifier.

controlled area: an area where the annual dose received by a worker is likely to exceed three-tenths of the annual dose limit.

deterministic effects: biological responses whose severity varies with radiation dose. A dose threshold usually exists

dose: Amount of energy absorbed by an irradiated object per unit mass.

dose equivalent: radiation quantity used for radiation protection purposes that expressed dose on a common scale for all radiations.

dosimeter: Instrument for detecting and measuring exposure to ionizing radiation.

dynamic hip screw(DHS): implant which is mainly used to treat stable trochantric fracture. It allows secondary impaction of the fracture along the axis of the gliding femoral neck screw.

effective dose: sum over specified tissues of the products of the equivalent dose in a tissue and the weighting factor for that tissue.

exposure time: the time an x-ray tube is energize and a useful beam produced.

fracture table: table which can break into portion where the surgeon can easily gain excess to the operative field.

fluoroscopy: X-ray imaging in real time.

-**intermittent fluoroscopy:** periodic activation of the fluoroscopic tube.

-**image intensifier:** electronic vacuum tube that increases the brightness of a fluoroscopic image.

Gray (Gy): SI unit of absorbed dose. It is equal to 1 J of energy absorbed from any type of ionizing radiation in 1 kg of any irradiated object.

interlocking nail (ILN) of femur: a surgical procedure where a rod-like implant (nail) is inserted through the medullary cavity of the femur. The rotations of the implant is prevented by placing screws over the proximal and distal part of the implant.

irradiated: substance which is exposed to ionizing radiation.

Internal System of Unit (SI): Standard system of units base on the meter, kilogram and second adopted by all countries and used in all branches of science.

Miliampere (mA): measure of x-ray tube current.

MINT: Malaysian Institute for Nuclear Technology.

occupational exposure: radiation exposure received by radiation workers.

Rad (radiation absorbed dose): special unit for absorbed dose. 1 rad = 0.01 Gy

real time: display for which the image is continuously renewed, often to view anatomical motion, fluoroscopy and ultrasound.

Rem: Special unit for dose equivalent and effective dose. It is replaced by the sievert (Sv) in the SI system. 1 rem = 0.01 Sv

piriform fossa: a depressed area over the very proximal part of femur around the trochantric area.

Scattered radiation: X-ray that change direction after an interaction with matter.

Sievert (Sv): Special name for the SI unit of dose equivalent and effective dose.

stochastic effect: probability or frequency of a biological response to radiation as a function of radiation dose. Disease incidence increases proportionately with dose and there is no dose threshold.

thermoluminescent dosimeter (TLD): Personnel monitoring device that contain sensing material.

threshold dose: a dose below which a person has a negligible chance of sustaining a specific biological response.

wilcoxan test: a statistical test to compare two parameters if there is any significance differences.

ABSTRAK (Bahasa Malaysia)

Bilangan kaedah pembedahan otopedik yang menggunakan bantuan paparan imej fluoroscopi (image intensification fluoroscopy) telah meningkat dengan banyaknya sejak beberapa tahun yang lepas. Terdapat kesangsian tentang kemungkinan adanya kesan buruk radiasi. Dalam kajian ini, pantulan rawak radiasi ke mata, tangan dan leher doktor bedah telah diukur semasa pembedahan memasukkan implant ke tulang peha (interlocking nail and dynamic hip screw) yang memerlukan bantuan mesin fluoroscopi. Dosimeter thermoluminescent telah digunakan untuk mengukur kuantiti dose radiasi yang diterima oleh doktor semasa pembedahan tersebut.

Purata masa pendedahan radiasi atau masa di mana fluoroscopi digunakan semasa kaedah pembedahan tulang peha 'interlocking nail' dan 'dynamic hip screw' adalah 3.89 minit dan 3.03 minit. Kajian menunjukkan doctor bedah telah menerima sejumlah kesan pantulan rawak radiasi semasa pembedahan tersebut. Tangan menerima kesan pantulan rawak radiasi yang tertinggi diukuti oleh mata dan leher. Kesan pantulan rawak radiasi ini adalah rendah. Analisis data dari kajian ini menunjukkan kemungkinan adalah amat rendah untuk seseorang doctor bedah menerima lebih dari had maksimum dose radiasi tahunan yang dibenarkan sebagaimana yang telah ditetapkan oleh badan antarabangsa.

ABSTRACT

The number of orthopaedic surgical procedures using image intensification fluoroscopic assistance had increased markedly over the past few years. There are growing concerns over possible associated radiation health hazards. In this study, scattered radiation to the eye, hand and neck of the primary surgeon were measured during interlocking nail of femur and dynamic hip screw fixation under fluoroscopic guidance. Thermoluminescent dosimeter was used to quantify the dose received by the surgeon.

Mean radiation exposure time or duration that fluoroscopy was used during the procedure for interlocking nail of femur and dynamic hip screw fixation were 3.89 minutes and 3.03 minutes respectively. Study showed that the primary surgeon received certain amount of scattered radiation dose during those procedures. The hand received the highest scattered dose followed by the eye and neck. The scattered dose was small. By extrapolating these results, it is unlikely for an individual surgeon to receive more than the recommended annual dose limit as set by the international organization.

1.0 INTRODUCTION

Orthopaedic surgeons are constantly working in closed proximity to x-rays. Fluoroscopy and radiography are increasingly being used for diagnosis and as an important aid during the operative fixation of the fractures. Over the past few years, the number and variety of the procedures utilizing fluoroscopic assistance have increased markedly. The used of fluoroscopy has now become an integral and essential part of the practice of orthopaedic surgery. As this machine produced ionizing radiation, we need to be aware of the potential hazard due to the repeated exposure to the radiation.(Fuchs at al. 1998; Friend, 2002)

The development of close interlocking intramedullary nailing and dynamic hip screw have allowed the orthopaedic surgeon to treat a larger variety of diaphyseal and proximal femoral fracture safely and effectively. A variety of implants had been designed. The insertion of all these implants relied on fluoroscopic control.

The hand of the surgeon is close to operating field and may be directly exposed to ionizing radiation.(Arnstein at al. 1994) Even though protective lead gloves may be used when screening an unstable fracture during a manipulation, many surgeons find them cumbersome and often prefer not to wear them.

Exposure to radiation can be associated with a range of harmful effects such as sterility, damage to the lens of the eye, the risk of developing neoplasm and skin necrosis (Lee et al., 2003). Ionizing radiation has therefore become a serious occupational hazard for the surgeons and other theatre staff who are often ill informed on the subject and poorly trained to minimize the associated risks.(Hynes at al. 1992)

The purpose of this study was to directly measure the scattered radiation dose to the hand, thyroid and eye of a primary surgeon during interlocking intramedullary nail of femur and dynamic hip screw fixation of proximal femur fracture.

2.0 THE IMPORTANCE OF THE STUDY

Orthopaedic surgeons are frequently exposed to scattered radiation during various procedures performed under the image intensifier. Unfortunately information on how much the scattered radiation dose received by the surgeon is not known in our local setting. The surgeon seldom wears the thyroid shield to protect the thyroid gland and rarely uses lead goggles to protect the eyes.

The surgeons, residents and operation theatre staffs do not have personnel monitoring devise to measure the radiation dose unlike their colleague in radiology department. Under the Radiation Protection (Basic Safety Standard) Regulations 1988, it stated that the doses received from external exposures shall be measured by the use of one or more approved personnel monitoring devices carried continuously on every person working in the 'controlled area'. Controlled area is an area where the annual dose received by a worker is likely to exceed three-tenths of the annual dose limit.

This study therefore is important to quantify the scattered radiation doses received by the surgeon during the procedure under fluoroscopic guidance technique and to predict whether the recommended annual dose limit is likely to be exceeded.

3.0 LITERATURE REVIEW

3.1 *History*

The carcinogenic potential of ionizing radiation was recognized soon after Roentgen's discovery of X-rays in December 1895. By 1902, the first radiation-induced cancer was reported arising in an ulcerated area of the skin. Within a few years, a large number of such skin cancers had been observed, and the first report of leukemia occurring in five radiation workers appeared in 1911.

3.2 Definition of radiation

Radiation is a general term used to describe the process of emitting radiant energy in a form of waves or particles. Simply, radiation can be define as energy in transit. When the word 'radiation' is used alone it usually refers to ionizing radiation.

Ionizing radiation produces positively and negatively charged particles as it passes through matter. Source of ionizing radiation can be manmade, for example; x-ray, nuclear power and nuclear waste or it can be natural background such as cosmic rays from the sun or radioactive material from the earth crust. It can also be in a form of particles (particulate radiation) or pure energy having neither mass or charge such as electromagnetic radiation (Dowd,1994).

3.3 Radiation Unit

Four units are used to express an amount of radiation (Table 3.1). They are two types of units; traditional and SI (Systeme International). In some country, it is still customary to use the traditional units but most country used SI units.

Table 1: Radiation Units

Quantity	Traditional Unit	SI Unit
Exposure (measured in air)	Roentgen (R)	coulombus per kilogram (C/kg)
Absorbed dose	rad	gray (Gy)
Dose equivalent (occupational)	rem	sievert (Sv)

3.4 Absorbed Dose

As ionizing radiation pass through an object, some of the energy of that radiation will be transferred to the object. Some of the radiation that is transferred to the object is absorbed (i.e., stays within the object). The quantity, 'absorbed dose', is define as the amount of energy per unit mass absorbed by the irradiated object. This absorbed energy is responsible for whatever biological damage occurs as a result of tissues being exposed to radiation (Statkiewicz et al, 1993).

The rad (traditional unit) and gray; (Gy; SI unit) are used to express the absorbed dose. The fraction of radiation absorbed depends on the energy or penetrating ability of the radiation and the composition of the absorbing material. This is called the *f-factor.*

The rad can be used for any type of ionizing radiation. Patient dose is often expressed in rad or grays. One gray is equivalent to 100 rad. It represents a specific quantity of energy absorbed. The draw back in the two units lies in the fact that the biological effect of 1 rad or 1 Gy varies with the type of radiation. (Dowd, 1994).

3.5 Occupational exposure (Absorbed dose equivalent)

Absorbed dose equivalent provides a method with which to calculate the effective absorbed dose for all types of ionizing radiation, including proton and neutrons as well as x-rays. It has been found that equal absorbed doses of different types of radiation produce different amounts of biological damage in body tissue. The absorbed dose equivalent take this into consideration by using modifying or quality factor

Absorbed Dose Equivalent = Absorbed dose X Quality factor

Traditionally, the rem has been used as the unit of the absorbed dose equivalent and may be define as absorbed dose equivalent of any type of ionizing radiation that produces the "same biological effect" as one rad of x-ray. One rem of neutrons will thus represent a different absorbed dose than does one rem of alpha particles. An absorbed dose in rad may be converted to a dose equivalent by use of a quality factor for the type of radiation being considered .

Rem mean *r*adiation *e*quivalent *m*an and is a traditional unit. The SI unit is sievert (Sv). In diagnostic radiology the three basic units are considered interchangeable. 1 R = 1 rad = 1 rem = 0.01 Sv since the factor are both approximately 1 for x-ray of these energies. The sievert (Sv) is equivalent to 100 rem. It is the SI unit that produces the same biologic effect as 1 Gy of high energy. x-ray. 1 Sv is equivalent to 1000 milisievert (mSv) (Dowd, 1994).

3.6 Image Intensification Fluoroscopy

Intraoperative image intensification fluoroscopy is commonly used in surgical procedure. It is the main source of ionizing radiation to the orthopaedic surgeon (Hynes at al. 1992). Image intensification fluoroscopy has three significant benefits:

1. Increased image brightness.

2. Saving of time for the radiologist.

3. Patient dose reduction.

The x-ray image intensification system converts the x-ray image pattern into a corresponding amplified visible light pattern. Overall brightness of the fluoroscopic image increases to 7000 times the brightness of the image on a conventional fluoroscopic system operating under the same conditions. This image brightness increase permits the radiologist increased perception of the fluoroscopic image.

Because an image intensification system permits viewing of the fluoroscopic image at ordinary brightness level (regular white light), the radiologist uses photopic or cone vision when viewing the image through this system. Because cone vision can be used, the radiologist does not need to go through the process of darkness adaptation; this saves time. Cone vision also considerably improves visual acuity, permitting the radiologist to better discriminate between small fluoroscopic images.

Because an image intensification system significantly increases brightness, image intensification fluoroscopy requires less milliamperage than does conventional fluoroscopy (about 1.5 to 2 mA is required for image intensification systems, whereas 3 to 5 mA is required for conventional fluoroscopy). The consequent decrease in exposure rate results in a reduction in dose for the patient.

3.6.1 Intermittent fluoroscopy

The practice of intermittent fluoroscopy (periodical activation of the fluoroscopic tube by the radiologist rather than lengthy, continuous activation) significantly decreases patient's dose, especially in long procedures, and helps to extend the life of the tube. Many systems include a "last-image-hold" feature that allows the radiologist to see the most recent image without exposing the patient to another pulse of radiation. This kind of fluoroscopy is commonly used in orthopaedic practice.

3.6.2 Limitation of the size of the fluoroscopic field

The radiologist must limit the size of the fluoroscopic field to include only the area of clinical interest by properly collimating the x-ray beam by adjusting the lead shutters placed between the fluoroscopic tube and the patient. When fluoroscopic field size is limited, patient dose decreases substantially.

Both primary beam length and width need to be confined within the image receptor boundary. Irrespective of the distance from the x-ray source to the image receptor, the useful beam should not extend outside the image receptor.

3.6.3 Filtration

The function of a filter in fluoroscopy as in radiographic procedures is to reduce the patient's skin dose. Adequate layers of aluminum-equivalent material placed in the path of the useful beam remove the more harmful lower energy photons from the beam by absorbing them. A minimum of 2.5 mm total aluminum-equivalent filtration must be permanently installed in the path of the useful beam of the fluoroscopic unit. With image intensification systems, a total aluminum-equivalent filtration of 3.0 mm may be preferred. Patient dose decreases by one fourth during fluoroscopic procedures when aluminum filtration increases from 1 mm aluminum to 3 mm aluminum.

3.6.4 Source-to-tabletop distance

The source-to-tabletop distance must be not less than 15 inches (38 cm) for fixed fluoroscopes and not less than 12 inches (30 cm) for mobile fluoroscopes. This ensures, as previously discussed (see p. 181), that the entrance surface of the patient does not receive excessive exposure. This reduces the exposure of the patient as well as that of the radiographer.

3.6.5 Cumulative timing device

A cumulative timer must be provided and used with each fluoroscopic unit. This device times the x-ray exposure and sounds an audible alarm after the fluoroscope has been activated for 5 minutes. It makes the radiologist aware of the length of time for which the patient receives exposure during each procedure and enables the staff radiographer to determine patient exposure for each fluoroscopic examination. When the fluoroscope is activated for shorter periods of time, the patient and the radiologist and radiographer receive less exposure.

3.6.6 C-arm fluoroscopy

C-arm fluoroscopes are frequently used in the operating room for orthopedic procedures (e.g., pinning of a fractured hip). This piece of equipment can be manipulated in almost any position and can be in an energized state for long periods of time to accommodate the surgeon during the procedure. Personnel routinely operating a C-arm fluoroscope or those who are in the immediate area of the unit should wear a protective apron. This garment should be 0.5 mm lead equivalent to ensure adequate protection. Appropriate monitoring of personnel normally involved in C-arm fluoroscopic procedures should be a routine procedure (Statkiewicz et al.,1993).

3.7 Detection Instruments

Radiation is not detectable by ordinary means that is, we cannot see, hear or feel it. The detection of radiation requires instruments specifically designed to detect ionizing radiation. This is done indirectly by measuring the effect radiation has on medium such as air (ionization) or film (density).

Dosimetry is the determination by scientific methods of the amount, rate and distribution of radiation emitted from a source of ionizing radiation. A dosimeter is a device used to detect and measure exposure to radiation. In radiation therapy, a dosimetrist is an individual who plans an optimal radiation treatment dosage pattern. There are two general classes of instruments used to detect ionizing radiation. They are field survey instruments and personal monitors.

There are three basic types of personnel monitors: film badges, thermoluminescent dosimeters and pocket ionization chambers. The desirable characteristics of personnel monitoring devices are (1) portability; (2) ability to withstand stress; (3) sensitivity; (4) reliability and (5) low cost. Each of these criteria must be evaluated when deciding which personnel monitoring system is to be used. In general monitoring is performed in any situation in which an individual is expected to receive 10% of the Effective Dose Equivalent (formally called MPD or maximum permissible dose) (Dowd, 1994).

3.7.1 Thermoluminescent Dosimeters (TLD)

TLD can provide accurate and precise measurement for both patient and personnel dosimetry in the medical imaging environment. (*Health Phys* 1990 Dec;59 (6):827-36) TLD materials are supplied in powder form and solid discs, rods and chips. This light-free device most often contains a crystalline form (powder or small chips) of lithium fluoride, which functions as the sensing material of the TLD.

Ionizing radiation causes the lithium fluoride crystals in the TLD to undergo changes in some of their physical properties. When irradiated, some of the electrons in the crystalline lattice structure absorb energy and are "excited" to higher energy levels or bands. The presence of impurities in the crystal causes these electrons to become trapped within these bands. When the lithium fluoride crystals are passed through a special heating process, these trapped electrons receive enough energy to rise above their present locations into a region called the conduction band. From here, the electrons can return to their original or normal state with the emission of energy in the form of visible light. The intensity of the light is proportional to the amount of radiation that interacted with the crystals. A device called a TLD analyzer (Fig. 9-9) measures the amount of ionizing radiation to which a TLD badge has been exposed by first heating the crystals to free the trapped, highly energized electrons and then recording the amount of light emitted by the crystals (which is proportional to the TLD badge exposure).

3.7.1.1 Reading Process

Read out of dose is achieved using specialized instrumentation. The TLD material is heated either by direct contact with a heated tray or by hot gas. The heating cycle is divided into a series of stages.

Pre read: A low temperature is applied to the TLD to fade any low temperature traps.

Read: A higher temperature is applied to the TLD material to liberate the electrons caught in the electrical traps and release light for collection and measurement.

Anneal: A high temperature is applied to ensure that all electrons have been removed from the electrons traps. This process sets the sensitivity of the TLD and therefore it is important that batches of TLDs are annealed together. Separate annealing ovens are often used for this purpose.

The TLD is finally allowed to cool. The exact temperature and length of each part of the cycle is determined by the TLD phosphor used. Light emitted by the TLD material is measured using a photomultiplier, which converts the light into a current signal which is then amplified and displayed. It should be noted that the read out count is dependant on the temperature and duration of the annealing cycle and the section of the glow curve sampled during read out. It is essential, therefore, that both of these are predetermined and fixed for any particular batch of TLDs used.

3.7.1.2 Advantages

Among the advantages are that the TLD is re-usable. Automated read out is also available. It is capable of measuring over a wide range of doses. Small physical size make it possible to place almost anywhere.

The thermoluminescent dosimeter has several advantages over the film badge. The lithium fluoride crystals interact with ionizing radiation as human tissue does; hence this monitor determines dose more accurately. Exposure 5 mR can be measured with precision. Humidity, pressure, and normal temperature changes do not affect the TLD. Unlike the film in the film badge, which can fog if worn for more than 1 month, the TLD may be worn for as long as 3 months. After the TLD reading has been obtained, the crystals can be reused. This makes the device somewhat cost-effective, even though the initial cost is high (approximately twice the cost of a film badge service).

3.7.1.3 Limitations

The TLD has few limitations. Immediate read out is not possible. The precision can be affected by poor handling and storage. Fading can occur , i.e. the unintentional release of trapped electrons in a thermolumnescent material prior to read out. Fading may be caused by exposure to heat (thermal fading), or light, particularly ultraviolet (optical fading.) For this reason TLD materials should be stored away from strong light or heat sources.

Light emission is related to the total mass of phosphor present and therefore any loss of mass or scratches on the surface of the TLD will affect the light emission characteristics. Contamination of the TLD material with grease or adhesives used to secure the device to a patient will affect precision. For this reason it is important not to handle TLDs directly and to use vacuum rather than mechanical tweezers.

3.7 Biological Effect of Ionizing Radiation

Ionizing radiation produces damage in living systems by ionizing the atoms composing the molecular structures of these systems. An ionized atom will not bond properly into the molecules necessary for the normal functioning of an organism.

The universal nature of radiation as a carcinogen relates to a specific characteristic of ionizing radiation that differentiates it from chemical toxic agents or other physical carcinogens, which are usually tissue specific in their action. This is its ability to penetrate cells and to deposit energy within them in a random fashion, unaffected by the usual cellular barriers presented to chemical agents. All cells in the body are thus susceptible to damage by ionizing radiation; the amount of damage will be related to the physical parameters that determine the radiation dose received by the particular cells or tissue (John B Little, 2000).

Radiation to the eye can induce cataract. Evidences come from the lab experiment on mice and observation group of people who accidently received substantial doses of radiation to the eyes. Thyroid carcinoma can occur as a late effect of radiation especially in children. There are also reports that ionizing radiation result in skin necrosis (Jin et al,2003).

Human response to radiation exposure are classified as either early effects which are termed *deterministic effects* and late effect also known as *stochastic effects.* (Bushong; 1998)

3.8.1 Stochastic effects

The term stochastic literally means "random in nature." This is also called the statistical response, which means that the probability of occurrence of effects increases in proportion to radiation dose of the entire population. It is assumed that stochastic effects do not exhibit a threshold. They are associated with the linear and the non-linear quadratic dose-response curves.

An analogy that may be helpful to remember this concept is investing money. If this money (radiation dose) is invested in the lottery, there is only a small chance that any return will be seen. There is no threshold in that someone or some amount of people will receive a payoff (have a radiation effect). As the amount of money invested increases, the individuals investing that money have a greater (though still remote) chance of winning, and the overall cash pot (number of effects) increases.

Thus, a stochastic effect, especially at diagnostic levels where doses are low, puts the odds heavily in one's favor that no effect will occur. An unlucky few (who cannot be predicted because it is random chance) will experience an effect. Radiation risks from diagnostic imaging, with the exception of in utero exposure of a viable fetus, are considered to be stochastic. Heredity effects and carcinogenesis are considered to be stochastic.

3.8.2 Deterministic Effect

Non-stochastic effects increase in severity with dose and a threshold is assumed. In 1991 the ICRP recommended using the term deterministic rather than non-stochastic. They are also sometimes called certainty effects because at high doses such as in radiotherapy, it is assumed that certain effects will occur, such as skin erythema or cataracts. They are associated with the sigmoid dose-response curve.

Our investment analogy holds here also. Here, the money would be invested in a savings account, and we are certain of some kind of return, unless the amount Invested is too low (threshold). Most banks, for example, would not accept a deposit of 50 cents to open an interest-bearing account. Thus, below a certain amount, no effect would occur.

Cataract induction, nonmalignant damage to skin, hematologic deficiences, and impairment to fertility are considered nonstochastic effects. The dose must be high enough to begin the effect, at which point the probability of an effect occurring is fairly high. (Statkiewicz et al.,1993).

3.9 Protective Devices

Protective lead aprons and gloves should be used whenever the person involved *cannot* remain behind a protective lead barrier during an exposure. If the peak energy of the x-ray beam is 100 kVp, a protective lead (Pb) apron must be equivalent to a 0.25 mi-n thickness of lead. A lead apron of 0.5 or 1 mm lead equivalent would afford greater protection. All three of these thickness are available for protective apparel. However, the 0.5 mm lead equivalent is the *most* widely used thickness in diagnostic radiology. During fluoroscopic examinations, the radiographer should always wear a protective apron. Protective lead gloves of a minimum of 0.25 min lead equivalent should be worn whenever the hands must be protected from the beam.

Because there is usually no protective barrier (i.e., control booth or moveable shield) present, lead aprons must be worn by radiographers during fluoroscopic and mobile radiographic procedures. For the latter the 6 foot long exposure cord, when fully extended, affords a significantly reduced exposure level because of the inverse square law.

A neck and thyroid shield of 0.5 mm lead equivalent can protect the thyroid area of occupationally exposed people during general fluoroscopy and x-ray special procedures.

Scatter radiation to the lens of the eyes of diagnostic radiology personnel can be substantially reduced by wearing protective eyeglasses with optically clear lenses that contain a minimum lead equivalent protection of 0.35 mm. Side shields on the protective glasses are also available for procedures that require turning of the head.

3.10 Recommended Radiation Dose Limit

In early twentieth century radiation dose limits were call tolerance doses. Then from 1940 to1990 radiation dose limits were known as maximum permissible dose. Currently occupational radiation dose limits are referred to simply as recommended dose limits. It is express as **effective dose** (E). Recommended dose limit for radiation workers are set at a risk level comparable to that for workers in other industrial. For the general public they are set at a risk level comparable to those experienced by the public under other similar circumstances.

Recommended dose limit are based on both stochastic and deterministic effects. A stochastic radiation response is one in which the probability of occurrence increases with increasing effective dose. This response is an all-or-nothing response. A deterministic radiation response increases in severity with increasing effective dose. It does not occur below the dose threshold. Recommended dose limit are all below the threshold value for deterministic radiation response. Much higher radiation doses are required for deterministic response then for stochastic responses.

The recommended annual dose limit for the lens of the eye is 150 mSv (15,000 mrem). For the extremities as well as thyroid the recommended dose are 500 mSv (50,000 mrem) (National Council on Radiation Protection and Measurements Report 91, 1987). Regardless of recommended dose limits radiation protection practices should be geared to implement ALARA i.e maintain dose as low as reasonably achievable. (Bushong., *1998)*

3.11 Principal of ALARA and Organizations That Derive Standard

As a long term potential risks of radiation have become known, radiation protection standards has focused on minimizing the potential long and short term effects. Today radiation protection programs are base on a simple philosophy that is to maintain exposures of patient, general public and personnel as low as reasonably achievable (ALARA). ALARA assumes that the relationship between dose and risk is strictly linear and without threshold. Although this may be an overly conservative model, it is desirable to overestimate rather than underestimate the risk.

Many organizations contribute to radiation protection standards. Some report on scientific research into radiation and its effects, some make recommendations for standards. The major players in this arena are Internasional Commission on Radiological Protection (ICRP), National Council on Radiological Protection (NCRP), Conference of Radiation Control Program Directors (CRCPD) and the National Research Council Committee on the Biological Effects of Ionizing Radiation (BEIR).