Assessment of Secondary Shielding of the Mammography Room of Al-Hussaini Hospital in Karbala City, Iraq

Header S. Jaafer, Abdullah A. Rasheed

Kerbala university/ College of medicine /Department of medical physics
AL-Mustansiriya university/College of Science/Department of Physics

Abstract

X-ray equipment must be installed in adequately shielded rooms to ensure that public in the vicinity of the x-ray installations are not unduly exposed to x-ray radiation. The adequacy of shielding depends on the material and thickness used for this purpose. This work therefore studies the secondary shielding of the mammography room. By considering the mammography room design and the radiographic devices profiles used , the clinical total workload per week and total workload per patient have been computed and its distribution according to the most widely used voltages has been determined by recording the actual clinical technical values of maximum ,average and minimum mAs and the corresponding values of kilovolt peak for 2119 women over six months. As a diagnostic x-ray radiation shielding reference, the National Council on Radiation Protection and Measurements report No.147 (NCRP report No.147) and XRAYBARR computer program have been used to compute the secondary barrier thicknesses of Gypsum and Wood of the mammography room.. It is found that the total workload per week and the total workload per patient of the room were about three times that of stated by the NCRP report No.147 for a half value of the patients.The required thicknesses of Gypsum and Wood were about 4 mm and 20 mm respectively, whereas the actual thicknesses are higher than these values ,furthermore ,another conventional materials were used as secondary barriers ,such as bricks and concrete, hence the secondary barriers thicknesses exist in the room are more than adequate.

الخلاصة

ان اجهزة الاشعة السينية يجب تنصيبها في غرف ذات تدريع كاف لضمان عدم تعرض الجمهور في محيط تجهيزات الاشعة السينية لاشعاع الاشعة السينية بنحو غير ملائم.ان كفاية التدريع تعتمد على المادة والسمك المستخدم لهذا الغرض ولذلك يدرس هذا العمل التدريع الثانوي لغرفة التصوير الشعاعي للثدي.بأعتبار تصميم غرفة التصوير الشعاعي للثدي ولمحة عن اجهزة التصوير الشعاعي المستخدمة تم احتساب حمل العمل السريري الكلي في الاسبوع وحمل العمل الكلي لكل مريض كما تم تحديد توزيعها وفقا للفولتيات الاكثر استعمالا من خلال تسجيل الحد الاعلى,متوسط والحد الادنى لقيم الـ (mAs) وقيم ذروة الكيلو فولت المناظرة لـ (2119) امرأة على مدى ستة اشهر.كمصدر لتدريع اشعاع الاشعة السينية التشخيصية فأن تقرير المجلس الوطني للحماية من الاشعاعات والمقاييس رقم 147 (NCRP report No.147) وبرنامج الكمبيوتر (XRAYBARR) تم استخدامهما لحساب اسماك الحاجز الثانوي من الجبس والخشب لغرفة التصوير الشعاعي للثدي.لقد وجد ان حمل العمل السريري الكلي في الاسبوع وحمل العمل الكلي لكل مريض كان حوالي ثلاث اضعاف ما يحدده تقرير إن سي آر بي رقم 147 (NCRP report No.147) لنصف مقدار المرضى. الاسماك المطلوبة من الجبس والخشب كانا حوالي 4ملم, 20 ملم على التوالي في حين ان الاسماك الفعلية اعلى من ذلك فضلا عن ذلك فأن مواد تقليدية اخرى كالطابوق والخرسانة استخدمت كحواجز ثانوية لذا فأن سمك الحواجز الثانوية اكثر من كافية.

Introduction

Diagnostic X-rays are the largest man-made source of radiation exposure to the general population, contributing about 14% of total worldwide exposure from man-made and natural sources[1],in spite of the risk that the radiation from a mammogram might cause breast cancer is extremely low, especially with the use of low-dose mammography[2] nevertheless if the x-rays are not shielded such that they only interact with the intended locations, they are potentially hazard to the workers, patients and members of the public [3]. The purpose of radiation shielding is to protect workers and the general public from the harmful effects of ionizing radiation [4]. The review of radiation shielding conditions is necessary when the designing assumptions change [5-7]. Shielding design of diagnostic imaging facilities has been a subject of several research works during the last years [8-11]. These working programs resulted on the publication of recommendations from the National Council on Radiation Protection (NCRP) in US in 2005[4,5] . The National Council on Radiation Protection and measurements report number 147 (NCRP 147) provides the widely accepted methodology for radiation shielding designing. The new NCRP report, No.147 has released to overcome the complexities and problems raised in applying the previous recommendations. For all modern mammography units, the primary beam is intercepted by the image receptor assembly. European [12] and US [13] guidelines permit only a very narrow strip of the primary beam to overlap the image receptor assembly along the chest wall edge of the beam. This radiation is usually attenuated to insignificant levels by the patient and, consequently, only secondary radiation must be considered for radiation protection purposes in mammography rooms. Furthermore, it is reasonable to assume that radiation scattered by the patient is the dominant source of secondary radiation, given the minuscule leakage intensity observed at mammography accelerating potentials[14]. In this work we present an assessment of the secondary barrier of In the mammography room at AL –Hussaine hospital of kerbala city. The shielding review was based on the NCRP report No.147.The calculated total workload per week and workload per patient were compared with that of recommended by NCRP report No.147.

Materials and Method

Determination of workload and clinical workload distribution

In the planning of a radiation installation, the maximum workload and of the number of radiation workers employed should be taken in account. Traditional shielding methods have assumed that a conservatively high total workload per week is performed at a single high operating potential, this assumption ignores the fact that the medical imaging workload is spread over a wide range of operating potentials, The distribution of workload as a function of kVp is important, as the attenuation properties of barriers exhibit strong kVp dependence, hence for radiography room, to have a curate shielding calculation the accurate value of maximum workload and workload distributions are required. To obtain this purpose the average number of patients per 36 actual hour work and corresponding technical exposure parameters of average with minimum and maximum mAs where recorded. The most voltages used by the radiographers are 29 kvp which is used during an automatic exposure control or they used 30 and 31 kvp when the automatic exposure control is not operated or when radiographers use manual exposure. The values of milliamperage corresponds to 29,30 ,31 kvp vary according to the thickness of the breast and the back up time. The maximum , minimum and the average mAs, the total workload,total workload per patient, and the most used image field For 2119 women over six months of digital mammography room in AL-Hussaine hospital of kerbala city is given in table 1 . The mean workload in terms of mA min wk^{-1} was calculated according to NCRP 147 [5].The mammography room contains digital mammography system type general electric company type senograph essential sterotaxy model No.144831-6-2010.Since the clinical workload distribution gives a better shielding estimate, the average clinical workload distribution for the working voltages of 29,30,31 kvp of the studied x-ray room is shown in figure 1.The program, "XRAYBARR" by Douglas J. Simpkin[15] has been used rather than the equations and graphs of NCRP 147. This program, which is able to make calculations for up to 5 distinct X-ray tubes in one installation, utilizes the algebraic and iterative approach mentioned in NCRP No. 147.

Geometry of the room, occupancy and use factor

The geometry of studied room is shown in figure 2.The dimensions of the room are (5.953×3.22) m^2. Only secondary radiation must be considered for radiation protection purposes in mammography rooms. According to the geometry of the room wall 3 is the nearest secondary barrier ,whereas wall 4 is the farthest wall and exist behind the protective viewing screen.

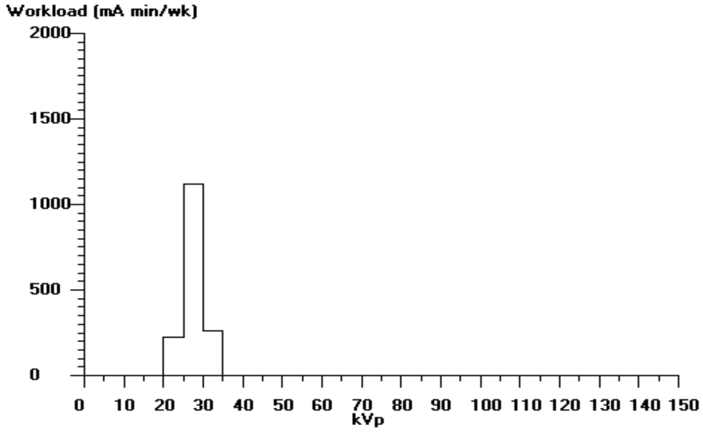

Figure 1.Workload distribution of the mammography room

Area behind wall 1 is an uncontrolled area with the maximally-exposed individual which is a corridor ,thereby the occupancy factor is 1/5 .Area behind wall 2 is an X-ray control room so the occupancy factor according to NCRP 147 is (T=1).The area behind wall 3 is a garden hence it is supposed that a given member of the public would spend an average of 1 h $week^{-1}$ in that area (while the x-ray beam is activated) every week for a year ,so the occupancy factor is 1/40 .For wall 4 the adjacent area is an x-ray control room which means that the occupancy factor is a unity. Since all the walls of the room are considered as secondary barriers ,the use factor for shielding calculations is a unity.

Table 1. Technical data and calculated workload x-ray room studied

kvp	Maximum mAs	Minimum mAs	Average mAs	Average Number of patients per week (N)	Total workload (W_{tot}) mA min wk^{-1}	Total workload per patient (w_{nor})	Image field (cm2)
29	334	78.2	206.1	78	1607.5	20.6	210
30	320	73.6	196.8				
31	309	62	185.5				

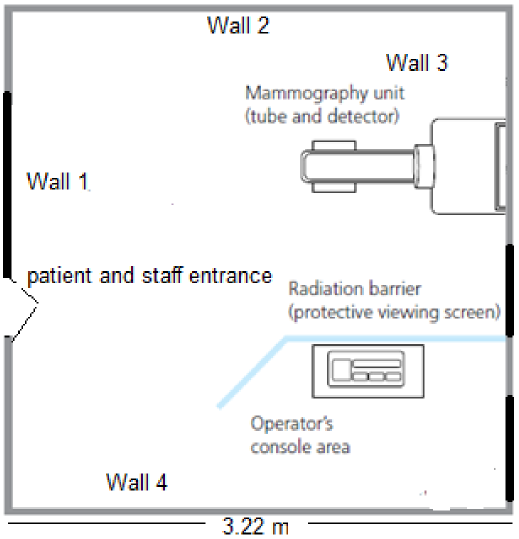

Figure 2.The geometry of mammography examination room

Secondary barriers calculation

According to the National Council on Radiation Protection and Measurements (NCRP) report No. 147[5] Permanent mammography installations may not require protection other than that provided by typical gypsum wallboard construction. Furthermore, adequate protective barriers of lead acrylic or lead glass are usually incorporated into dedicate mammography imaging systems to protect the operator Although the walls of mammography facility may not require lead shielding, a qualified expert shall be consulted.The national council on radiation protection and measurements (NCRP) report No.147 states that for typical four view mammograms the unshielded air kerma at 1 m from mammographic units is:

$$K^1_{sec} = 0.036 \text{ mGy patient}^{-1}$$

For secondary barriers calculation using NCRP No.147 ,the air kerma from unshielded secondary radiation $K_{sec}(0)$ at a distance d_{sec} for N patients per week is

$$Ksec(0)=\frac{k^1_{sec}N}{d^2_{sec}} \quad (1)$$

The isocenter of the mammographic equipment is located 2 m from wall 1 which is the most occupied wall and the area behind this wall is a a fully-occupied uncontrolled area, hence

$$Ksec(0)=\frac{0.036\ mGy\ pat^{-1}\times 78\ pat\ wk^{-1}}{(2\ m)^2} = 0.702 \text{ mGy wk}^{-1}$$

The area behind wall 2 is corridor uncontrolled area with shielding design goal of

$$\frac{p}{T} = \frac{0.02}{0.2} = 0.1 \text{ mGy air kerma}$$

Where p is the shielding design goal, so the required transmission of the wall according to NCRP report No.147 is given by

$$B_{sec}(x_{\ barrier}) = \frac{\frac{p}{T}}{k_{sec}(0)} \quad (2)$$

Then the required transmission would be

$$B_{sec}(x_{\ barrier}) = \frac{0.1}{0.702} = 0.14$$

By using the NCRP report No.147 curves for transmission of secondary radiation through Gypsum wallboard represented by Figure 3, the barrier requirement on graph is about 4 mm of Gypsum.

Doors in mammography rooms may need special consideration since wood does not attenuate x rays as efficiently as gypsum wallboard[5], so the shielding status of the door must be determine. The door is about 2.5 m from the mammographic unit, then the air kerma from unshielded secondary radiation $K_{sec}(0)$ at 2.5 m with the same number of patients per week will be

$$Ksec(0)=\frac{0.036\ mGy\ pat^{-1}\times 78\ pat\ wk^{-1}}{(2.5\ m)^2} = 0.449 \text{ mG wk}^{-1}$$

The geometry of the room shows that the door is in the wall 1 ,and since NCRP report No.147 states that for a corridor door the occupancy factor is (1/8) , then The required transmission for the corridor door is

$$B_{sec}(x_{\ barrier}) = \frac{0.02/0.125}{0.449} = 0.356$$

This transmission of the secondary radiation make the required thickness of wood according to NCRP report No.147 curves of wood shown in figure 4 is about 20 mm wood door.

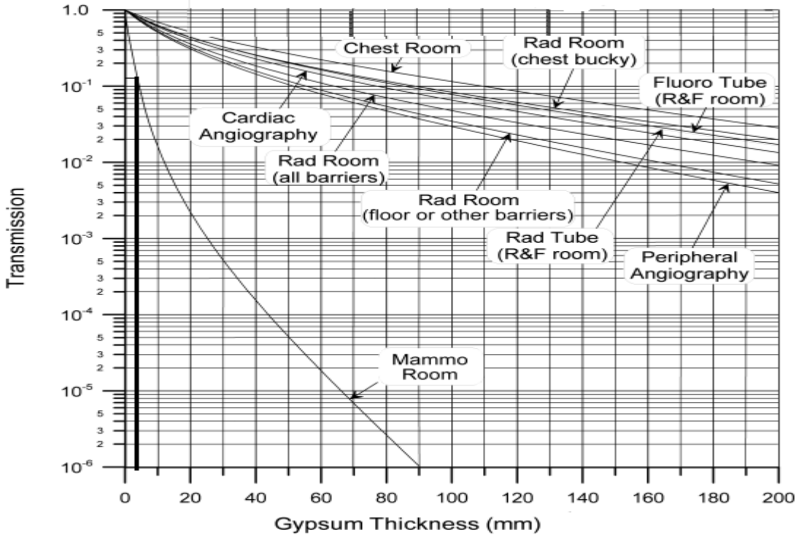

Figure 3. Transmission of secondary radiation through Gypsum

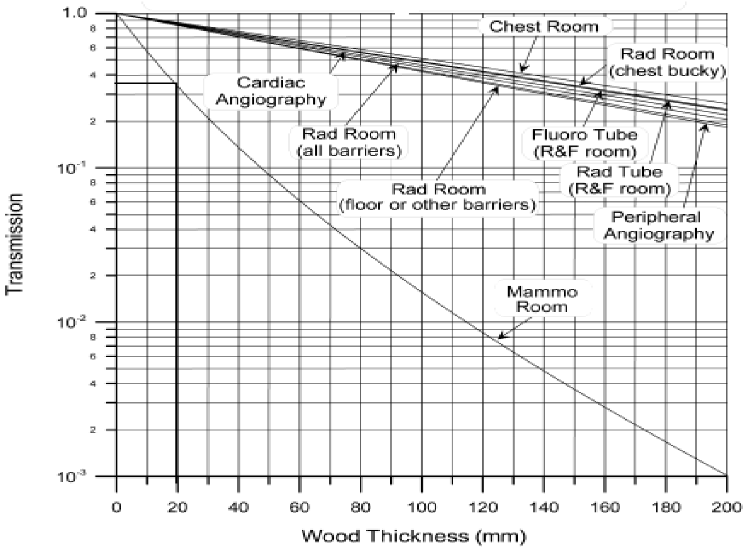

Figure 4. Transmission of secondary radiation through wood

Results and discussion

The workload distribution of the mammography room in figure 1 shows that the most usable voltage is a 29v kvp., which is used during the automatic exposure control. The values of voltages in mammography depend on the breast thickness which must be lower for small thickness breast and in the case of large beast the kvp must be raised, this is not the case for the automatic exposure control which is fixed on 29 kvp, furthermore it is clear from table 1 that the maximum workload in all cases of voltages is very high ,this indicates that there is increasing in automatic exposure timing and this leads to high absorbed dose in the breast since in an automatic exposure control an excessively high dose might not be noticed because it probably would not cause image quality problems, unlike with screen film, where the image overexposure would be obvious. As shown in table 1 the typical number of patients per week is 78 whereas NCRP report No.147 determined an average of 80 patients and 160 patients for busy clinics and hospitals as shown in table 2 which presents a comparison between the typical number of patients per week, the total workload per week and the total workload per patient for NCRP report No. 147 and the corresponding data of our study. In spite of that the number of patients per week in mammography room of our study is less that of the NCRP report

No.147 nevertheless, the total workload per patient is 20.6 which is three times that of the recommended value of NCRP report No.147 ,also the total workload of the room was about three times that of NCRP report No.147 for an average number of patients and about 1.5 times for busy operation. These values of workload confirm the fact that there were excessive values of mAs used for each exposure case and this leads to an excessive number of x-ray photons during each exposure. The barrier thicknesses using XRAYBARR v 1.2 by D.J. Simpkin, are shown in table 3 .It is very clear that the required thickness of Gypsum wall board for mammography room according to simpkin is about 2.6 times that of our study and the same thing for wood, this difference is due to the total patients per week input. The XRAYBARR v 1.2 states 240 patients per week which is about three times the patients that included in our study.

The materials that are actually used for shielding in the room are: Bricks, Concrete and Gypsum with roughly thicknesses. The net effects of Using these materials together made the shielding status of the room excellent and the actual materials exist are more than the requirements even for many times of patients per week and these added thicknesses provide an increased measure of protection.

Table 2. Comparison of workloads and number of patients obtained from NCRP 147 and the calculated values from the room under study

	Total Workload per patient (mA min/patient)	Number of Patients (per 40 hour week)		Total Workload per week (mA min/week)	
		Average	Busy	Average	Busy
NCRP 147	6.7	80	160	550	1075
calculated	20.6	78		1607.5	

Table 3. secondary barrier thicknesses of shielding materials using XRAYBARR v 1.2of the mammography room .

material	thickness
Lead	0.0334 mm = 1.3E-3 inches
Concrete	3.97 mm = 0.156 inches
Gypsum	10.7 mm = 0.422 inches
Steel	0.174 mm = 6.8E-3 inches
Glass	4.18 mm = 0.165 inches
Wood	63.6 mm = 2.5 inches

Conclusions

An important part of determining the radiation protection requirements during X-ray room design is the shielding, so for radiation protection purposes, it is important to ensure that the shielding provided by the walls, ceiling and floor of an X-ray room are adequate. Shielding must be sufficient to maintain radiation dose to staff and patients in adjoining areas below the regulatory limits [16] .In mammography shielding is required only to reduce exposure from scattered radiation, since the primary beam is limited to the area of the image receptor support, So accurate evaluation of the secondary radiation barriers is necessary since for assessment of shielding adequacy. In this study the secondary barrier of the mammography room has been evaluated according to NCRP report No. 147. It is found that the total workload per week and total workload per patient of the room was about three times that of NCRP report No. 147 for about half value of patients stated by NCRP report No.147. It is concluded that using automatic exposure control technique without review of doses received by the woman has considerable potential of increasing secondary radiation. For structural shielding of the room, the actual thickness of gypsum used as a secondary barrier is more that calculated ,further more using ,bricks and concrete add more barriers ,altogether the secondary barriers obtained from this assessment demonstrate that the present shielding is more than adequate.

References

1. United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and effects of ionizing radiation. New York: United Nations, 200
2. A Adjunct, W Lee, MA Revell, G Russell, J Bramley , Screening Mammography, The Royal Australian and New Zealand College of Radiologits,2013.
3. ICRP, 1990 Recommendations of the International Commission on Radiological Protection. ICRP Publication 60 annals ICRP 21 (1-3), 1991.
4. IAEA, International Basic safety Standards for Radiation Protection against Ionizing radiation and for the Safety of radiation sources, IAEA Safety Series No. 115 (Vienna, IAEA) ,1996.
5. National Council On Radiation Protection And Measurments. Structural Shielding Design for Medical X-ray Imaging Facilities. NCRP Publications, Bethesda, MD, (NCRP Report 147), 2004.
6. HPRH, The Health Physics and Radiological Health Handbook, Exposure and Shielding from external radiation, Scinta Inc. Publishers (USA), 1993.
7. ICRP, Protection against ionizing radiation from external sources in medicine, Pergamon Press, Oxford, 1982.
8. NCRP, Structural shielding design and evaluation for medical use of x-rays and gamma rays of energies up to 10 MeV. NCRP Report 49, Washington, DC, 1976.
9. ARCHER, B.R. History of the Shielding of Diagnostic X-ray Facilities. Health Physics, v.69,n. 5, p. 750-758, 1995.
10. SIMPKIN, D. Evaluation of NCRP Report No. 49 Assumptions on Workloads and Use Factors in Diagnostic Radiology Facilities. Medical Physics, v. 23, n.4, p.577-584, 1996.
11. SIMPKIN, D.J.; DIXON, R.L. Secondary Shielding Barriers for Diagnostic X-ray Facilities:Scatter and Leakage Revisited. Health Physics, v.74, n. 3, p. 350-365, 1998.
12. Perry N, Broeders M, de Wolf C, Tornburg S, Holland R, von Karsa L, eds. European guidelines for quality assurance in breast cancer screening and diagnosis. 4th edn. Luxemburg City, Luxemburg: European Commission; 2006.
13. FDA. Performance standards for ionizing radiation emitting products. Primary protective barrier for mammography x ray systems. Code of Federal Regulations. 21 CFR 1020.31(m). Washington, DC: U.S. Dept. of Health and Human Services. Food and Drug Administration; 2003.
14. Simpkin, DJ. Scatter radiation intensities about mammography units. Health Phys, 70:238–44, 1996.
15. Simpkin, DJ.xraybarr software, x-ray shielding calculation, 1996-2000.
16. Johnson CH, Walker A. Technical note: the measurement of mammographic room protection. Br J Radiol, 67:494–6, 1994.