Original paper

Study the Primary Barrier of the Digital Chest X-Ray 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

Background: structural shielding are fundamental to controlling the exposure of the workers as well as the exposure of the general public.
Aim of the study: The objective of the present work is to assess the primary shielding of the digital chest x-ray room of Al- Hussaini hospital in Karbala city
Materials and method: The technical data of minimum ,maximum and average of mAs and the corresponding values voltages of the chest x-ray procedures for 1134 patients over two months have been used to calculate the total workload per week and total workload per patient based on the National Council on Radiation Protection and Measurements report No.147 (NCRP report No. 147).
Results and discussion : It is found that the workload per week was about 4.5 times that of recommended by NCRP report No.147 ,whereas the workload per patient was about five times that of stated by NCRP report No.147 for the same number of patients per 36 actual work hour week for busy situation. By adoption the equations of NCRP report No.147 the required thickness of lead as primary barrier was 2.7 mm or 184 mm from concrete.
Conclusion: The thicknesses of Bricks, Concrete and Gypsum that were actually used were highly enough to be used as a primary shielding barrier.
Keywords: Primary barrier, x-ray room

الخلاصة

ان التدريع الإنشائي أساسي في السيطرة على التعرض للعمال فضلا عن عامة الجمهور.ان الهدف من هذا العمل هو تقييم التدريع الأساسي لغرفة الاشعة السينية للصدر الرقمية لمستشفى الحسيني في مدينة كربلاء.البيانات التقنية من الحد الأدنى, الحد الأقصى ومتوسط الـ (mAs) وقيم الفولتيات المناظرة من اجراءات الاشعة السينية لـ (1134) مريض على مدى شهرين استخدمت لحساب حمل العمل الكلي في الأسبوع وحمل العمل الكلي لكل مريض مستندا الى تقرير المجلس الوطني للحماية من الإشعاعات والمقاييس رقم 147(NCRP report No.147) .لقد وجد ان حمل العمل لكل اسبوع كان حوالي 4.5 أضعاف ما يوصي به تقرير إن سي آر بي رقم 147 (NCRP report No.147), بينما ان حمل العمل لكل مريض كان حوالي خمسة اضعاف ذلك المحدد من قبل تقرير إن سي آر بي رقم 147 لنفس العدد من المرضى لكل 36 ساعة عمل فعلية في الاسبوع لحالة ناشطة.بأعتماد معادلات تقرير إن سي آر بي رقم (147) فأن السمك المطلوب من الرصاص كحاجز أساسي كان 2.7 ملم او 184 ملم من الخرسانة.في الواقع لم يكن هناك رصاص كحاجز أساسي بدلا من ذلك فأن سمك الطابوق , الخرسانة والجبس كانت كافية جدا لاستخدامها كحاجز تدريع أساسي.

Introduction

X-rays have over the years become an important tool in medical diagnosis and therapy. However, 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

*For Correspondence: Headjaf.2009@yahoo.com

public [1,2]. The purpose of radiation shielding is to protect workers and the general public from the harmful effects of ionizing radiation [3]. The review of radiation shielding conditions is necessary when the designing assumptions change [4-6]. Shielding design of diagnostic imaging facilities has been a subject of several research works during the last years [7-10]. These working programs resulted on the publication of recommendations from the National Council on Radiation Protection (NCRP) in US in 2005 [3]. 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. In report No.147, for primary barrier shielding calculation, it is recognized that the primary beam is reduced due to attenuation by the patient, the image receptor, and the structures supporting the image receptor [11-13]. A study was designed to compare the effect of adapting new guidelines on optimizing the primary shielding barrier thickness in a digital chest x-ray room. In the current study, the thickness of the primary shielding barriers for the chest x-ray room was calculated based on actual clinical workload and by using NCRP reports No.147. The calculation methods and the results were analyzed and compared to the actual existence.

Materials and Method

Determination of workload and clinical workload distribution

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, 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 radiographers use automatic exposure control fixed on milliamperage of 320 mA but with different backup times so the mAs different relative to backup time. This value of milliamperage corresponds to 70 kvp.The second value of milliamperage is 160 mA, also with different backup times and the corresponding voltage is 80 kvp.The maximum, minimum and the average mAs, the total workload per week, the voltages with the source to image distance SID For 1134 patients over two months of dedicated chest x-ray room in AL-Hussaine hospital of kerbala city is given in table 1 . The total workload in terms of mA min wk^{-1} and the total workload per patient were calculated according to NCRP 147[3] .The chest x-ray room contains digital chest x-ray system type general electric GE health care.Since the clinical workload distribution gives a better shielding estimate, the average clinical workload distribution for the two working voltages of 70 kvp and 80 kvp of the studied x-ray rooms is shown in figure 1 by using " XRAYBARR"[14] computer program by Douglas J. Simpkin .

Geometry of the room, occupancy and use factor

The geometry of studied room is shown in figure 2.The dimensions of the room are 5.3m ×6.8 m .According to the geometry of the room wall 1 uses to stand the chest bucky, so it is a primary barrier and since the area behind wall 1 is an uncontrolled area (outdoor area with seating),hence the occupancy factor according to NCRP 147 is (T=1/20).The radiographers did not use the supine position and cancel the table and they always use the chest bucky ,hence the use factor for wall 1 is a unity (U=1).Walls 2,3 and 4 are secondary barriers, so the use factor for all the three barriers is one (U=1).For wall 2 the outdoor area adjacent 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 .

According to the geometry of the room of figure 2 the adjacent area of wall 3 is a corridor thereby the occupancy factor is 1/5 .For wall4 it is clear that the adjacent area is an x-ray control room which means that the occupancy factor is a unity.

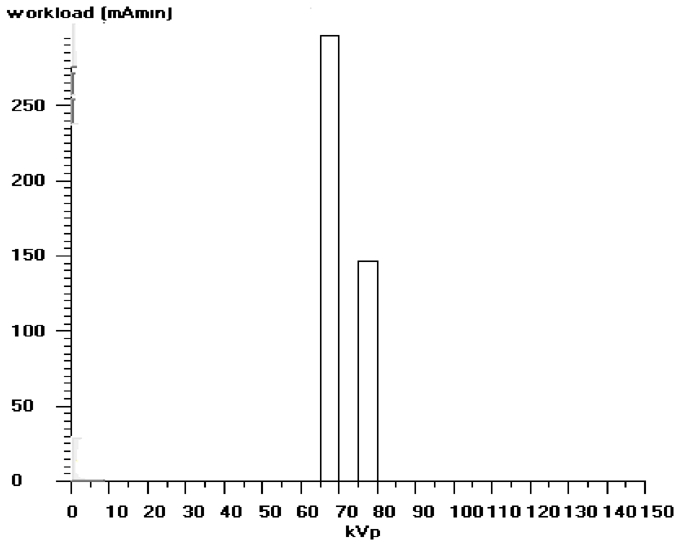

Figure 1.The workload distribution of the chest x-ray room.

Table 1. Technical data and calculated workload of the chest x-ray room.

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}	Average Source to image distance (SID) (cm)
70	46	12.5	29.25	420	443.66	1.05	110
80	75	11	43				

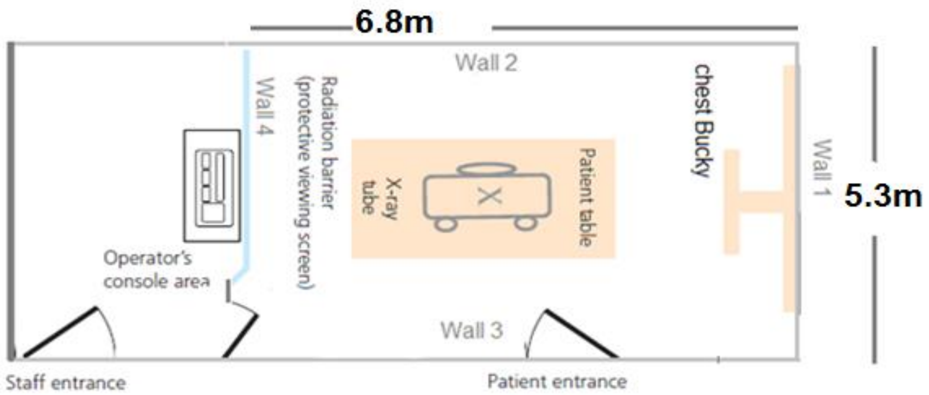

Figure 2.The geometry of chest x-ray examination room

Shielding thicknesses calculation

According to the geometry of the digital chest x-ray room, the x-ray tube used is directed horizontally toward the wall 1,so all the walls except wall 1 are assumed as secondary barriers and wall 1 is assumed primary barrier .According to NCRP report No.147 The weekly unshielded primary air kerma ($K_{P(0)}$) in the occupied area due to N patients examined per week in the room is:

$K_{p(0)}=k_p^1\ U\ N/d_p^2$ ....………… (1)

Where K_P^1 is the Unshielded primary air kerma per patient and its value according to NCRP report No. 147 is 1.2 mGy patient^{-1} , U is the use factor (U=1) , N the number of patients per week (N=420) and d_P is the distance (in meters) from the x-ray tube to the occupied area(outdoor area with seating) .the measurement shows that d_p=2 m.

Hence the weekly unshielded primary air kerma will be

$K_{p(0)}=\frac{1.2\times1\times420}{4}=126\ mG\ week^{-1}$

and since the area here is uncontrolled area ,so the weekly shielding design goal should be 0.02 mGy air kerma, thereby the required barrier transmission is

$B_p=0.02/126=1.58\times10^{-4}$

By using the NCRP report No. 147 of primary transmission curve for lead represented by Figure 3, the required thickness of lead is 2.7 mm.

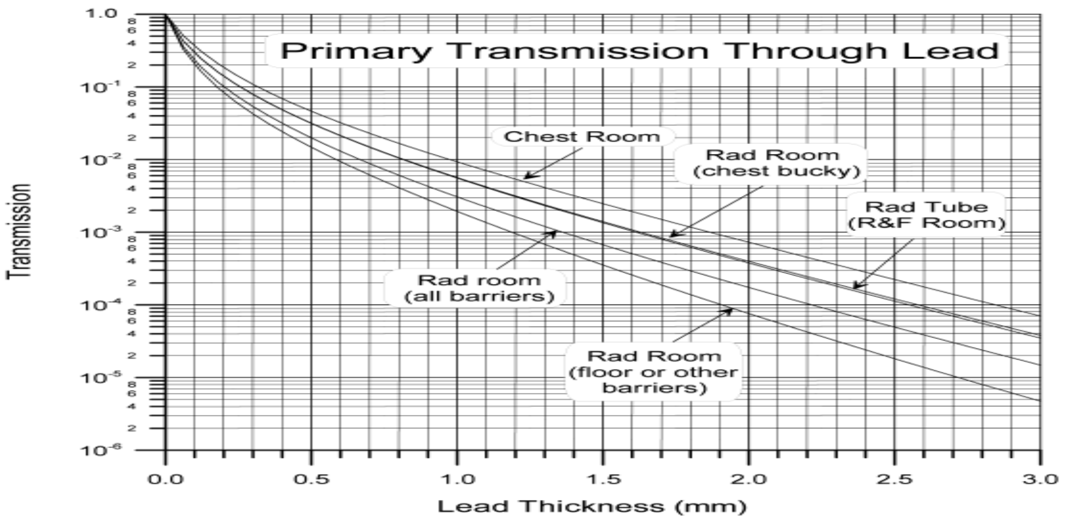

Figure 3: Primary transmission through lead calculated for the clinical workload distributions

Results and discussion

Figure 1 and Table 1. Show that the clinical values of kvp are limited in spite of the high number of examinations per week, furthermore the values of kvp are low, these have a direct effect on the patients radiation doses [15]. Table 2.presents the typical Number of Patients (per 40 hour week), total Workload per patient in (mA min/patient) and total Workload per week in (mA min/week) for average and busy chest rooms obtained from NCRP report No.147 and those calculated by the current work. It can be seen that the calculated total workload per patient is about five times that of NCRP report No. 147 and the total workload per week of the room under study is about 4.5 times that of recommended by NCRP report No.147 taking into account the same number of patients per 36 actual work hour week for busy situation used. This indicates that the radiographers use high mAs for the clinical examinations of chest x-ray ,and this is another factor that increases the potential of exposing patients to unbenefit and a gratuitous radiation and since the digital x-ray has high dynamic range the radiographers could perform the required examinations with less amount of mAs and thus less radiation.Table3 compiles the results of calculations for primary barrier thicknesses of shielding materials using XRAYBARR v 1.2 computer program by D.J. Simpkin(14).The actual materials used for shielding of primary and secondary walls of the digital x-ray room do not contains lead and for all the walls ,the shielding materials are Concrete ,Bricks and Gypsum. Bricks vary greatly in their attenuation but usually concrete is used with bricks .The thickness of concrete used in the room is highly enough to give the required NCRP report No.147 weekly shielding design goal.

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	0.22	200	400	50	100
calculated	1.05	420		443.66	

Table 3. calculated primary barrier thicknesses of shielding materials using XRAYBARR v 1.2of digital chest x-ray room under study.

material	thickness
Lead	2.65 mm = 1 / 9.59 inches
Concrete	184 mm = 7.25 inches
Gypsum	573 mm = 22.6 inches
Steel	23.7 mm = 0.933 inches
Glass	198 mm = 7.78 inches
Wood	1282 mm = 50.5 inches

Conclusions

Shielding design for X-ray imaging facilities has been established by scientific international committees. These recommendations were adopted in many countries and were partially incorporated in their national laws on protection against ionising radiation. The National Council on Radiation Protection (NCRP) report No. 147 is still the basis of many methodologies used to shield radiography installations. The calculated workload per week and workload per patient of the digital chest x-ray room were compared to that recommended by NCRP report No.147.It is found that the workload per week is about 4.5 times that of stated by NCRP report No.147 whereas the workload per patient is about five times that of NCRP report No.147 for the same number of patients per 36 actual work hour week for busy situation. According to NCRP report No.147 the primary barrier of the room should contain lead with 2.7 mm thickness but actually there was no lead used instead the Concrete, Bricks and Gypsum thicknesses used were high enough such that they are sufficient as a primary shielding.

References

1. ICRP, 1990 Recommendations of the International Commission on Radiological Protection. ICRP Publication 60 annals ICRP 21 (1-3), 1991.
2. 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.
3. NATIONAL COUNCIL ON RADIATION PROTECTION and MEASUREMENTS. Structural Shielding Design for Medical X-ray Imaging Facilities. NCRP Publications, Bethesda, MD, (NCRP Report 147), 2004.
4. HPRH, The Health Physics and Radiological Health Handbook, Exposure and Shielding from external radiation, Scinta Inc. Publishers (USA), 1993.
5. ICRP, Protection against ionizing radiation from external sources in medicine, Pergamon Press, Oxford, 1982.
6. 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.
7. ARCHER, B.R. History of the Shielding of Diagnostic X-ray Facilities. Health Physics, v.69,n. 5, p. 750-758, 1995.
8. 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.
9. 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.
10. DIXON, R.L.; SIMPKIN, D.J. Primary Shielding Barriers for Diagnostic X-Ray Facilities: A New Model. Health Physics, n.74, v.2, p. 181-189, 1998.
11. ARCHER, B.R. Recent history of the shielding of medical X-ray imaging facilities. Health Physm, 88: 579-586, 2005.
12. ARCHER, B.R. and GRAY, J.E. Important changes in medical X-ray imaging facility shielding design methodology. A brief summary of recommendations in NCRP report No. 147. Med Phys, 32:3599-3601, 2005.
13. GRAY, J.E. and ARCHER, B.R. NCRP and AAPM revising NCRP 49. Health Phys, 67:297, 1994.
14. Simpkin DJ. xraybarr software, x-ray shielding calculation 2000.
15. Jenny K. Hoang , Terry T. Yoshizumi , Giao Nguyen , Greta Toncheva , Kingshuk Roy Choudhury , Andreia R. Gafton , James D. Eastwood , Carolyn Lowry and Lynne M. Hurwitz. Variation in Tube Voltage for Adult Neck MDCT: Effect on Radiation Dose and Image Quality. Medical Physics and Informatics, Volume 198, Number 3, March 2012.