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Effective doses in chest and abdominal radiography following the ICRP recommendations of 1991 and 2007 in a regional hospital.

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ABSTRACT

Background: In 2007, the International Commission for Radiological Protection (ICRP), published a new set of tissues and tissue weighting factors as recommendations in the ICRP publication 103. This altered the parameters contributing to the calculation of effective dose, which is normally used as a single indicator of risk.

Purpose: To assess the effect of the 2007 review of tissue weighting factors on measured doses in a clinical setting, using patient doses for chest (CXR) and abdominal (AXR) radiography.

Materials & Methods: Patient entrance surface doses(ESD) obtained in a dose audit for chest (CXR) and abdomen (AXR) examinations with Harshaw type Lithium Fluoride thermoluminescent dosemeters (LiF-TLD 100) were used in a Monte Carlo calculation software, XDOSE, developed by the National Radiation Protection Board (NRPB) to calculate organ doses. Effective doses (E mSv) were calculated with both the ICRP 1991 and 2007 recommendations of tissue weighting factors. A 2-sample t-statistic was used to test for differences between the results for both recommendations. Tests were at the 95% confidence interval.

Results: The mean effective doses for CXR were found to be 0.04 (range 0.019 to 0.092) mSv and 0.03 (range 0.011 to 0.069) mSv for the 1991 and 2007 recommendations, respectively. Mean abdominal effective dose values were 0.78 (range 0.16 to 2.98) mSv for the 1991 w_T factors, and 0.49 (range 0.099 to 1.97) mSv for the 2007 recommended factors. The mean percentage difference between the effective doses calculated with w_T recommendations of 1991 and 2007 respectively came to 1.7 ± 0.6 % with a range between 0.8 and 3.3 % for CXR ($p < 0.05$) and 35.9 ± 5.6 with a range of 20.8 to 42.3%, for AXR ($p = 0.05$).

Conclusion: Effective doses showed statistically significant differences between the values calculated from the 1991 and 2007 w_T values for chest radiography. There is however, insufficient evidence to accept a difference for the abdominal effective doses. Wider studies are required to confirm this result.

Introduction

Diagnostic Radiology doses have witnessed a reduction of about 50% (Chest x-rays) and 60% (abdominal x-rays) from values in the mid 1980s [1-2]. This reduction is in keeping with the as

low as reasonably achievable (ALARA) requirement for radiology examinations. The achievement of these low doses is important in the face of the increase in the frequency of radiological procedures. According to the National Radiological Protection Board (NRPB), over 40 million x-ray examinations were conducted annually in the United Kingdom (UK) [3] with an average frequency of 0.7 examinations per person. Recent studies have shown a general annual increase in the number of examinations performed [4]. An average dose of 330 μSv/person is the result of the increased frequency of x-ray examination in the United Kingdom (UK) [4]. It is reported that exposure from all medical procedures has risen by about 10%. However, the bulk of this increase is due to computed tomography (CT) examinations[4].

Although the contribution of conventional radiology doses from chest and abdominal radiography examinations is small, these examinations involve the irradiation of vital organs in the thoracic region. The International Commission for Radiological Protection (ICRP) issued new recommendations in 2007 for determining effective doses in radiology [5], with the review of the tissue weighting factors (w_T) of some organs. These recommendations are based on the incidence of radiation induced cancer and risk of heritable diseases over the first two generations. The risk of cancer, adjusted for severity and years of life lost, replaced the earlier criterion of mortality[5]. ICRP w_T values from 1977[6], 1991[7] and 2007 [5] are shown in Table 1.

The 2007 ICRP recommendations update the contribution of the radiation and tissue weighting factors to equivalent (H) and effective (E) doses. As a means of providing workable legislation for regulation, effective dose (E) has been widely used [8-10]. This is in spite of its being a subject of some controversy [11-13], arising from the limitations in its calculation and demographic data variation from the population used in deriving the conversion coefficients.

Table 1: ICRP recommended tissue weighting factors (1977, 1991 and 2007)

Tissue	Recommended Tissue Weighting factor (w_T)		
	1977	1991	2007
	Pub 26	Pub 60	Pub 103
Bone surfaces	0.03	0.01	0.01
U. Bladder		0.05	*0.04*
Breast	0.15	0.05	*0.12*
Colon		0.12	0.12
Gonads	0.25	0.20	*0.08*
Liver		0.05	*0.04*
Lungs	0.12	0.12	0.12
Oesophagus		0.05	*0.04*
Red bone marrow	0.12	0.12	0.12

Skin		0.01	0.01
Stomach		0.12	0.12
Thyroid	0.03	0.05	*0.04*
Remainder	0.30	0.05	*0.12*

Sources: [6, 7, 8].
Italicised figures indicate new w_T values.

This paper sought to assess the effect of the 2007 review of tissue weighting factors on measured doses in a clinical setting, using patient doses reported in earlier studies [14-16] for chest (CXR) and abdominal (AXR) radiography[17].

Materials and method

Entrance surface doses (ESDs) from an audit of 77 patients during radiography of the chest (PA), [14-16] and ESDs of 34 abdominal radiography patients [17] were adapted for this study. The patient doses used, had been obtained with thermoluminescence dosemeters (TLD). The values of entrance surface doses for the studied examinations used in this study, are compared to dose reference values in the UK for 2000 and 2005 surveys in Table 2.

Table 2: Comparison of ESD (mGy) used in the current study with the UK 2000 and 2005 DRLs

Projection	NDRL[+]	NDRL*	Doses used in this study
PA chest	0.2	0.15	0.17
AP abdomen	6.0	4.0	3.77

[+] 2000 recommended dose values [3]
* 2005 recommended DRLs [2]
# % difference between doses in this work and 2005 recommendations [2]

Following the practice of determining organ and effective doses from dose measurements with dose conversion coefficients [18,19], the adapted ESDs obtained from the TLD readout were used in a Monte Carlo calculation software, XDOSE, developed by the NRPB to calculate organ doses for each examination [20]. XDOSE runs on the Microsoft Disk Operating System (MSDOS) platform and computes organ doses using input from examination data of kVp, tube filtration, ESD and number of projections [21]. Effective doses (E mSv) were calculated with both the ICRP 1991 and 2007 recommendations of tissue weighting factors [5,6]. A 2-sample t-statistic was used to test for differences between the results for both recommendations.

Organ doses were selected based on the organ position relative to the primary beam. This implied that an organ like the testes (for which organ dose from chest x-ray was very low) was not included for calculation of effective dose for the chest

examination. The organ dose to the colon was determined from the mass weighted average of the doses to the upper lower intestine (ULI) and the lower part of the large intestine (LLI) following the ICRP recommendations.

Results

Effective doses obtained for CXR with the ICRP recommendations in publications 60 and 103, respectively, are shown in Figure 1. The mean effective doses are 0.04 (range 0.019 to 0.092) mSv and 0.03 (range 0.011 to 0.069) mSv for the 1991 and 2007 recommendations, respectively. The mean percentage difference between the effective doses calculated with w_T recommendations of 1991 and 2007 respectively came to 1.7 ± 0.6 % with a range between 0.8 and 3.3 %. Figure 1 shows the distribution of E under both regimes and the shift in mean value to the left. A two-sample t-statistic showed that these differences were statistically significant ($p < 0.05$, 95% C.I).

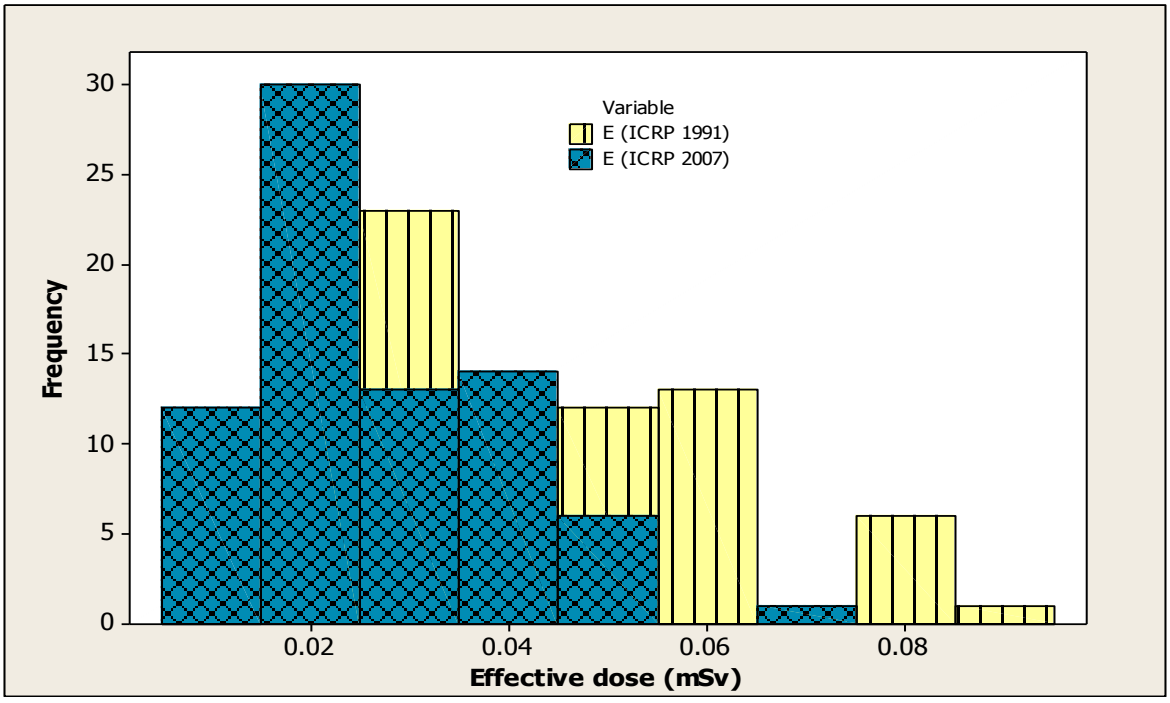

Figure 1: Distribution of E (mSv) in chest radiography calculated with 1991 and 2007 w_T respectively

The distribution of effective doses obtained for abdominal radiography is presented in Figure 2. Mean abdominal effective dose values were 0.78 (range 0.16 to 2.98) mSv for the 1991 w_T factors, and 0.49 (range 0.099 to 1.97) mSv for the 2007 recommended factors. The mean percentage difference between the effective doses came to 35.9 ± 5.6 with a range of 20.8 to 42.3%. There was

insufficient evidence to accept differences between the effective doses from the two recommendations (p = 0.05, 95% CI). Some organ doses obtained in the study are presented in Table 3, along with organ doses found in the literature.

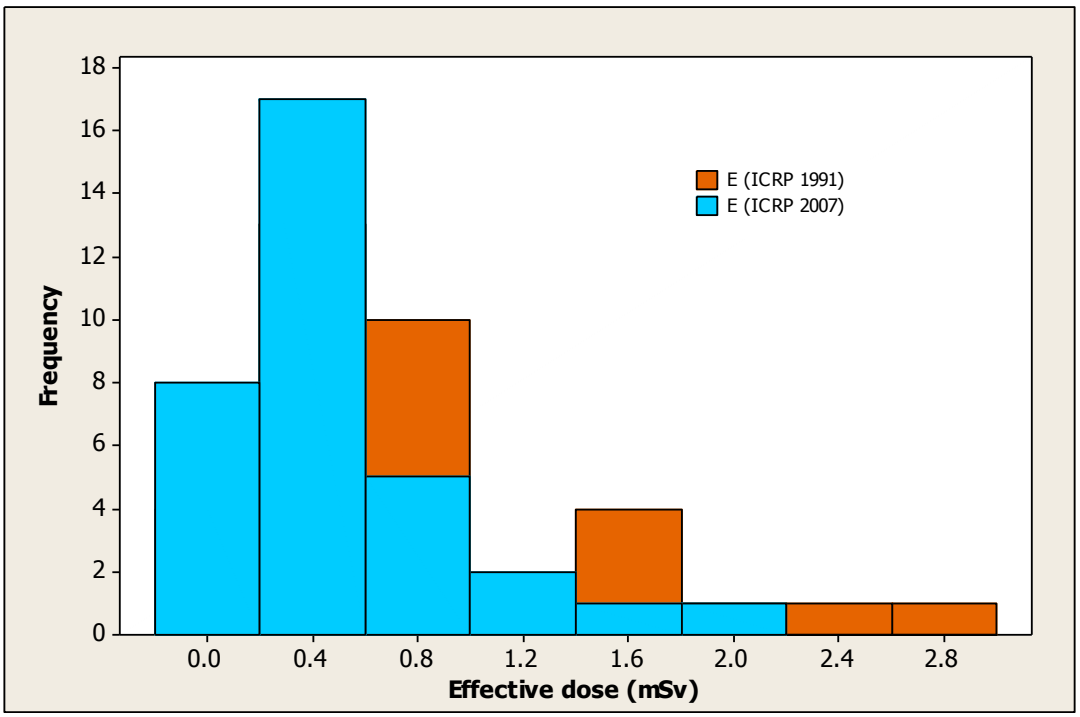

Figure 2: Distribution of E (mSv) in abdominal radiograph calculated with ICRP 1991 and ICRP 2007 w_T.

Table 3: Some organ (H_T) doses from this work compared with values in the literature

Organ	Mean organ dose (mGy)						
	This study		**(Kawuara et al.)**		**Begum**	**#Ogundare et al.**	
			2006		***2001***		***2009***
	CXR	*AXR*	*CXR*	*AXR*	*CXR*	*CXR*	*AXR*
Adrenals	0.09	0.19			0.25		
Breast	0.02		0.04	0.04	0.04	0.18	
Liver	0.04	0.66	0.12	0.16	0.10		
Gall Bladder	0.02				0.03		
Stomach	0.03	1.21	0.06	0.43	0.04		
Small intestine	0.003	0.99			0.0		
Heart	0.03				0.06		

Lungs	0.08		0.16	0.02	0.23	1.55	0.07
RBM	0.03	0.13	0.06	0.08	0.07	0.35	0.24
Oesophagus	0.04		0.11	0.07	0.09		
Thymus	0.02				0.03		
Skin	0.015	0.32	0.02	0.06	0.06		
Total bone	0.04	0.19			0.16		
Ovaries	<0.01	0.76	<0.01	0.37	0.0	<0.01	1.21
Testes		0.14	<0.01	0.02	0.0	<0.01	0.10
Thyroid	<0.01				0.02	0.13	<0.01
Pancreas	0.04	0.51			0.09		
Spleen	0.07	0.29			0.21		
Urinary bladder		1.64	<0.01	0.10	0.00		
Colon*		1.32	0.02	0.30	0.00		
Muscle		0.43			0.05		

* weighted average of doses to upper large intestine and lower large intestine (ULI/LLI).
RBM = Red bone marrow
[#]Mean values reported for male and female were used except for doses for ovary and testes.

Discussion

To determine the effect of the 2007 recommended tissue weighting factors on the effective dose of a cross section of patients in a UK hospital, clinical radiology doses from a dose audit for the examinations of interest (chest and abdomen), have been used to determine organ and effective doses, in the current study.

The requirement of correlation between ESD and radiation effects (detriment) based on empirical assumptions from biological and physical data [21] is satisfied in the ICRP definition of the effective dose [6]. This takes into account the fact that different target sizes, positions, and sensitivities are crucial to the overall detriment that could occur from any irradiation exposure.

Table 4: Effective doses (mSv) from this work and values from the literature

Projection	**USA**	**Germany**	**[$]Spain**	**Japan**	**[#]Italy**	**This work**	
						W_T **91**	W_T **07**
Chest	[§]0.07	[§]0.3	0.03	[§]0.05	0.02	0.04	0.03
Abdomen	-	-	0.88	-	0.32	0.78	0.49

W_T - tissue weighting factor in ICRP recommendation in year indicated
Sources: [§][23],[#][28], [$][29]

The ICRP has also recommended the use of absorbed dose to the irradiated tissues and organs or the equivalent dose for exposure planning and risk benefit assessments [21-22]. The mean values of organ doses for a selection of organs

determined for the population in this study are presented in Table 3. Compared with some data found in the literature, organ doses in this study were found to be higher than those reported in Kawaura et al.[10] by a factor of between 1 and 16. Differences in methodology and technique can account for this wide variation. Kawaura and colleagues [10] used an anthropomorphic phantom with technical parameters like the mean focus to image receptor distance (FID) of 200 cm against the 150 cm used in clinical chest radiography. Applied tube current recorded for both chest and abdominal radiography in this study was about 20 to 23 % higher than the values used by Kawaura et al.[10]. ESDs were monitored with photodiode dosemeters, as against the TLDs [14-15] in this work. These may all account for the more than 60% differences in effective dose, E (mSv) observed between the two studies.

A survey of patient doses in Japan by Begum [23] provides good comparison for organ doses in chest radiography (Table 3). Abdominal doses were not studied in the report of Begum[23], but the organ doses for chest radiography differ by a factor of between 1 and 4. Differences in exposure factors such as the kVp (50 to 80 kVp in the Japanese study against 102 -105 kVp in the current study), and FFD (114 – 200 cm for the Japanese study against 150 cm for the current study) would account for the differences in organ doses. Although both studies used sample populations of over 18 year olds, lower exposure factors may have been used for patients in the Japanese study considering physical stature. Differences in body build between the UK/European population and other people groups have been published by the International Commission for Radiological Protection [24].

The only study [25] with organ doses in the Nigerian radiology scene indicates organ doses which are remarkably higher than the values obtained in this study (Table 3). A comparison of organ dose to the lungs and breast from chest radiography reveal differences of 95 and 89%, respectively. Organ doses to the ovaries from AXR in this study are more than 30% lower than the Nigerian data. The organ dose values for the testes was at least 28% higher in the current study than the Nigeria data. The differences observed here may not be unconnected with the fact that very high entrance dose values were recorded in the referenced study[25] , which may be due to the low kVp and high current time product values reported in the study. Effective dose values were not provided.

Effective doses obtained in this work are 29.8% lower for the chest, and 69.2% higher for the abdomen than the values reported in UNSCEAR [26]. Compared with values in the literature (Table 4), effective doses in chest radiography vary by factors up to 10 with values calculated using the 2007 ICRP W_T values. Doses in abdominal radiography vary by up to a factor of 4 with values in the literature. Wider differences by factors up to 13 (chest) and 154 (abdomen) have been reported between effective doses in a study conducted across 12 countries in Asia, Africa and Eastern Europe[27]. Effective dose values of 0.88, 0.74 and

0.70 mSv for the abdomen and 0.02 mSv for the chest have been reported [3, 28, 29].

The effect of the 2007 ICRP review of tissue weighting factors on effective dose calculation with 13 remainder organs in place of the earlier 5 produces significant effects in chest radiography effective dose. However, further studies, perhaps with a larger population size may be required to confirm the results for the abdomen.

The wide range of individual patient parameters is one reason for the wide differences in E for different geographic locations and accounts for the current debate on the viability of effective dose as a unit of dosimetry [30].

Conclusion

Effective doses determined with the ICRP 1991 and 2007 recommended tissue weighting factors w_T, showed statistically significant differences for chest radiography. Similar results could not be confirmed for abdominal radiography effective doses for insufficient evidence. Wider studies are required to confirm this result.

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