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Radiation doses for barium meals in the Western Cape, South Africa

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Abstract

This study investigated the radiation dose received by patients referred for barium meal (BaM) examinations at three state hospitals in the Western Cape, South Africa (SA). Twenty-five participants (male and female patients) aged between 18 and 85 years and weighing 50 to 85 kilograms (kgs) were included in the study. The radiation dose to the participants was measured using a Dose-Area-Product (DAP) meter permanently fitted to the fluoroscopy equipment at the selected health facility sites. Measurements were done on digital fluoroscopy (DF) and conventional fluoroscopy (CF) units. The third quartile and median DAP values were 20.1 Gycm^2 and 13.6 Gycm^2 respectively. The median DAP value (13.6 Gycm^2) is recommended as the diagnostic reference level (DRL) for BaM examinations because this value is less affected by outlying values of under or overweight [1]. The relationship between DAP and patient weight, fluoroscopy time (FT), the number of images recorded, and the employment of DF or CF units, are discussed.

Keywords

Radiation protection, barium studies, reference dose levels, diagnostic reference level

Introduction

The use of ionising radiation in the diagnosis of disease and injuries increases the risk of stochastic radiation detriment [2, 3]. Requirements to deliver the lowest possible radiation dose consistent with the clinical purpose of a radiological examination are legally formalised [4]. One such requirement is the establishment of diagnostic reference levels (DRLs) for radiological examinations that are most frequently performed and contribute substantially to the collective dose and therefore the radiation risk. DRLs are radiation dose quantities that are usually set at the third quartile value or mean radiation dose obtained for standard sized adult patients or phantoms using a variety of equipment [2]. DRLs need to be easily measurable dose quantities that act as simple tests for identifying unusually high patient radiation dose levels that are not clinically justified. Such DRLs are not to be exceeded by departments operating under standard and normal diagnostic and technical practices [5, 6].

Hart and Wall [7] categorised barium contrast examinations as large contributors to the collective radiation dose from radiological examinations. Since there is no national DRL for BaM examinations in SA, the researchers chose to conduct measurements for this examination using the DAP meters that were permanently fitted onto fixed fluoroscopy units at three state hospitals in the Western Cape in South Africa (SA).

This paper focuses on the radiation dose measured for BaM examinations and recommends a DRL for such examinations. The effects of a patient's weight, fluoroscopy time, number of images obtained, and level of training of the radiologist performing the examination on the radiation dose, are discussed. This is the first published study that has measured radiation dose to patients referred for BaM examinations in SA hence its aim is to recommend possible DRLs.

Materials and methods

In 1992 a Dosimetry Working Party comprising members from the Royal College of Radiologists established protocols to follow when acquiring DRLs for radiological examinations [2]. These protocols recommend that dose measurements should be carried out on at least 10 adult patients weighing from 50 to 90 kilograms (kgs) so that the mean sample weight would be within 70kg ±5kg. This weight is considered a good indication of the typical weight of an average adult patient [2] and therefore appropriate for the calculation of a reference dose for an adult population. These protocols were followed in this study and the radiation dose to the patients (participants) was measured using DAP meters that were permanently fitted onto the fluoroscopy units. DAP meters were the preferred method of dose measurement because they provide a single direct measurement of radiation dose in an examination involving both radiography and fluoroscopy. The DAP meters used in this research are calibrated annually; this was ascertained from the quality assurance records of the x-ray departments at the three study sites. Care was taken to reset the DAP meters to zero for every new patient examined.

Three state hospitals in the Western Cape were identified as the research sites. In addition to having DAP meters permanently mounted onto their fluoroscopy units, these hospitals routinely perform BaM examinations on a large number of patients and employ either a DF or CF unit thereby enabling investigation of doses on both types of equipment. The specifications of the fluoroscopy units and DAP meters employed at the three hospitals are shown in Table 1.

The CF unit at hospital 1 was operated by a radiologist with more than 5 years' experience; the digital fluoroscopy units at hospitals 2 and 3 were operated by radiology registrars.

Permission to conduct the study at these hospitals was granted by the heads of the radiology department. The Cape Peninsula University of Technology also granted permission for the research to proceed. Additionally, the patients also

Table 1: The specifications of the fluoroscopy units and the DAP meters at the study sites

Hospital	1	2	3
Fluoroscopy unit type	Conventional	Digital	Digital
Manufacturer	Philips	Mecall	Philips
X-ray tube	Over-couch	Over-couch	Over-couch
Generator waveform	80 kW	80kW	80kW
Total filtration	2.7mm Al at 100kV	3.07mm Al at 70kV	2.5mm Al at 80kV
Inherent filtration	0.35mm Al	> 1.7mm	1.0mm Al
Motorised filters	0.1mmCu+1mmAl(100kV) 0.2mmCu+1mmAl(100kV)	0.1mmCu+0.5mm Al 0.2mm Cu+0.5mm Al	0.1mmCu+3.5mmAl(80kV) 0.2mmCu+7.1mmAl(80kV)
Film processor	Chemical processor	Laser printer	Laser printer
DAP meter	PTW, Diamentor	KermaX plus IDP	PTW, Diamentor

Table 2: Minimum, mean, maximum and standard deviation of the mean recorded at the three hospitals

Hospital number	Number of participants	Minimum DAP ($Gycm^2$)	Mean DAP ($Gycm^2$)	Max DAP ($Gycm^2$)	STDEV
1	4	10.5	20.9	36.9	11.8
2	11	5.7	18.8	42.1	10.8
3	10	6.6	12.5	25.1	5.3

Table 3: Mean and third quartile DAP values ($Gycm^2$) recorded for barium meals

Country	Mean DAP	3rd quartile DAP	Median DAP
UK[8]		13	
Ireland[9]		17	
Greece[1]	23.3		
Greece[12]	25		
Netherlands[13]	15 (digital unit) 28 (conventional unit)		
Spain[14]	39.85		
Serbia[10]	15	18	
Switzerland[15]	67		
This study	**16.6**	**20.1**	**13.6**

signed consent forms before the barium meal examinations allowing the researcher to include them in the study.

Male and female participants aged between 18 and 85 years and weighing 50 to 90kgs were included in the study. The mass (weight) of the participants was measured using calibrated digital bathroom scales (Safeway deviation ±100g) that were automatically reset to zero for every new weight measurement. All weight measurements were obtained with the participants wearing hospital gowns and no shoes.

The following data were captured: participants' ages, gender and weight; indication for the study; years of experience of radiologist; level of difficulty of examination; number of images obtained; kilovoltage peak (kVp); tube current time product (mAs); time of exposure (seconds); screening kVp tube current (mA);fluoroscopy time (minutes).

Results

Twenty-five (n=25) BaM participants with a mean age of 55 years and mean weight of 66.4kg were investigated. Table 2 shows the number of participants investigated at the hospitals and the DAP measurements recorded. The combined mean, median, first and third quartile DAP values were 16.6 $Gycm^2$, 13.6 $Gycm^2$, 10.4 $Gycm^2$ and 20.1 $Gycm^2$ respectively.

The relationship between the participants' weight and DAP, and fluoroscopy time and DAP were assessed by calculating the correlation coefficients as shown in Figures 1 and 2 respectively.

Participants' (patient) weight: there was no direct linear correlation between the respective weight of the participants and DAP measured ($R^2 = 0.0036$) as shown in Figure 1. The lack of a direct linear correlation was not statistically significant (p-value = 0.387).

Fluoroscopy time ranged from 4.17 minutes to 12.85 minutes with a mean of 8.13 minutes. The fluoroscopy times were only recorded for hospitals 1 and 3. The DF unit at hospital 2 only recorded the time for emission of each pulse of x-rays and therefore time measurements were not a true reflection of the total FT. There was no direct linear correlation between the DAP and FT ($R^2 = 0.42$) as shown in Figure 2. This relationship was not statistically significant ($p = 0.067$).

The radiologist operating the CF unit at hospital 1 recorded a mean number of 12 images whereas the mean number of images of 5 and 15 were recorded by radiology registrars operating DF units at hospitals 2 and 3.

Discussion

In terms of the recommendation to obtain DRLs it is necessary to carry out dose measurements on a minimum of 10 patients weighing 50 to 90kgs so that the average weight of the participants is 70kg ±5kgs: the average weight of an adult. The third quartile DAP value in this study was 35.3%, 15.4% and 10.4% higher than the DRLs in the UK [8], Ireland [9] and Serbia [10] as shown in Table 3. However, such variations are expected owing to region and country specific variations [4, 11]. Although third quartile DAP values have been recommended as the dose levels at which the DRL must be set, the median value of a series of values is a quantity that is less affected by extreme outliers such as under and over weight of the patients [1]. For this reason the median DAP value of 13.6 $Gycm^2$ recorded in this study was recommended as the DRL for the Western Cape, South Africa.

Despite various studies [10, 17] identifying the patient's weight as a factor responsible for dose variation, there was no direct linear correlation in this study between the weight of the respective

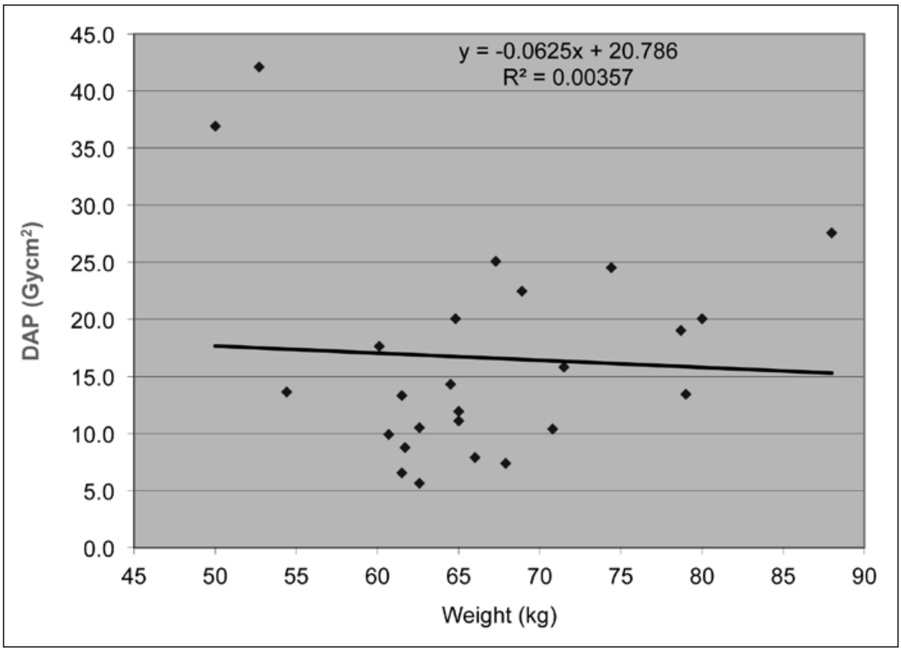

Figure 1: DAP (Gycm²) versus participant (patient) weight (kg)

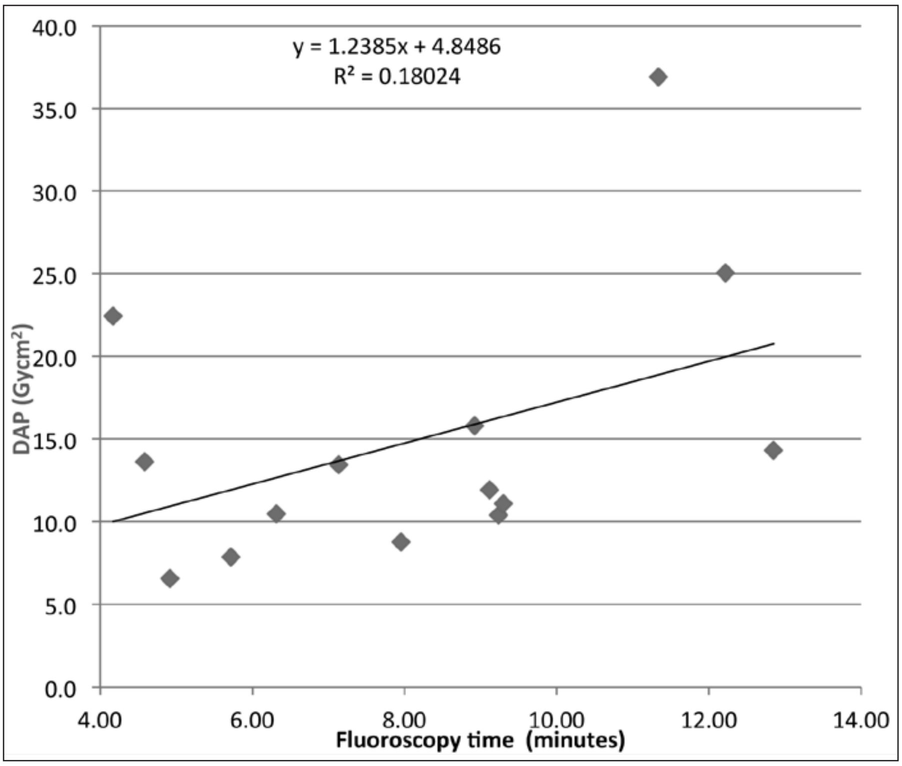

Figure 2: DAP (Gycm²) versus fluoroscopy time (minutes)

participants and the DAP (see Figure 1). This relationship was however not statistically significant (p = 0.387). The absence of a direct correlation between DAP and participants' weight in this study is probably associated with the fact that several participants in this small sample had complex diagnoses and were in an emaciated state. Upper gastrointestinal tract cancers are associated with severe weight loss [17] hence a patient weighing 50kgs and suspected of having stomach cancer may be irradiated for longer than a 60kg patient suspected of having a peptic ulcer. For example, the resultant DAP for the latter patient would be lower compared to that of the emaciated 50kg patient.

In this study there was no direct correlation between DAP and FT (R = 0.42) (see Figure 2) despite dose saving of 11% being reported with decreased FT [10]. This may be attributed to comparing persons with different levels of expertise: a radiologist at hospital 1 who operated the CF unit had >5 years' experience and was able to maintain lower FT versus radiology registrars at hospitals 2 and 3 who used the DF unit. The dose saving capabilities of DF [18, 19] compared to CF may have compensated for long FT recorded by the radiology registrars thereby resulting in lower DAP but long FT.

The combined mean number of images recorded at the there hospitals was 10 images. With the CF unit at hospital 1 it was found that 12 images were the norm during BaM procedures. The DF units at hospitals 2 and 3 allowed for post-processing of images thereby reducing the number of images acquired in the radiographic mode of imaging. There were no images acquired in the radiographic mode for one participant at hospital 2 since screening only was done during the examination.

Increased image noise is a shortcoming of imaging at low frame rates. In order to compensate the image noise arising from low frame rates, manufacturers increase the mA setting of the DF unit to allow acquisition of a good diagnostic image. With high mA settings the resultant radiation dose does not decrease by the same amount as the frame rate. For example, a frame rate reduction from 30 to 15 frames per second may result in 25% dose saving rather than the expected 50% dose reduction [18].

A step in realising the dose saving possibilities of DF is training of radiology personnel in the dose saving capabilities of such units without compromising image quality [20]. The increasing advancement in DF without additional training for radiology personnel using these units results in the under-utilisation of the dose saving features of the equipment.

In this study only four participants were examined using the CF unit which was not sufficient data to assess the dose saving capabilities of DF compared to the CF.

Limitations of the study

The results of this study are limited to public hospitals. At the time of the study the private sector did not perform sufficient BaM examinations to allow the data collection process to be completed within the allocated research time-frame. Additionally, only four participants were included in the study from hospital 1 because most patients were emaciated and weighed <50kgs which was the lower weight limit for inclusion in this study.

Conclusion

In this study the radiation dose, received by participants referred for BaM examinations at three state hospitals in the Western Cape in South Africa, was measured to establish a recommended DRL for this radiological investigation. The median DAP value of 13.6 Gycm^2 is recommended as the DRL because the median is less affected by extreme low or high patient weight. This DRL should be used as a guide. However, it is suggested that radiology departments should aim for lower DAP readings while maintaining good image quality. The third quartile DAP value (20.1 Gycm^2) recorded in this study was higher than third quartile DAP values recorded in the UK (13 Gycm^2), Ireland (17 Gycm^2) and Serbia (18 Gycm^2) thereby emphasising the need for region and country specific dosimetry measurements [11]. DAP measurement audits could be conducted in the future at these sites to determine whether the recommended DRL for BaM examinations at these sites should be revised and lowered.

There were no direct correlation between participant (patient) weight and DAP,or the fluoroscopy time and DAP. However, the absence of these direct correlations was not statistically significant.

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