Dose reference level for barium enemas at state hospitals in the Western Cape South Africa

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Abstract
Radiation doses for barium enema (BaE) examinations were measured using dose area product meters at three hospitals in the Western Cape in South Africa. Thirty adult patients, aged from 18 to 85 years, weighing 50-90 kilograms (kg), were included in the study. The mean age and weight of the patients were 58.3 years and 68.8 kg respectively. The mean DAP was 28.7 Gycm² and the third quartile DAP value was 36.5 Gycm². The mass of the patients, fluoroscopy time, and the use of digital or conventional fluoroscopy equipment, were the factors considered for dose variation between the three hospitals. The recommended dose reference level (DRL) for BaE at state hospitals in this region of South Africa is 36.5 Gycm².

Keywords
radiation protection, fluoroscopy, diagnostic reference level

Introduction
Barium enema (BaE) is a radiological examination of the colon where barium sulphate contrast medium is administered through the rectum to aid in radiological examination of the colon. This examination is indicated in congenital and inflammatory lesions, such as colitis, ulcerative colitis, Crohn’s disease, ischemic colitis, diverticular disease of the colon, and tumours of the colon such as polypoid lesions.[1] Previously BaE was the routine radiological examination of the gastrointestinal tract. However, with the advancement of radiological imaging modalities, such as computed tomography (CT), virtual colonography, magnetic resonance imaging (MRI), endoscopy, and ultrasound, with capabilities of tumour staging and high sensitivities for polyps and colon cancers, there is a decreasing frequency of BaE examinations.[2,3] Despite this BaE continue to be routinely performed in developing countries with less advanced modalities, and as an adjunct to failed or incomplete colonoscopy.[4,5]

The substantial biological and epidemiological evidence of radiation induced effects in man have motivated the concept of dose limits and control of radiation risks.[6] In the United Kingdom (UK), dose reference levels were adopted[7] to act as dose audits for quality control in radiology departments. In 1992, a Dosimetry Working Party in the UK devised national protocols that provided practical guidance for radiology departments in the use of these reference doses. In these protocols it was emphasised that departments must focus on dose levels for examinations that are most frequently performed and that contribute significantly to the collective dose and therefore the radiation risk.[8]

In South Africa (SA), protection of radiation workers and the public from unnecessary radiation exposure is continually emphasised.[9] Currently, it is a legal requirement for all fixed fluoroscopy equipment to have permanently fitted dose area product (DAP) meters thereby allowing real time monitoring of a patient’s radiation dose during fluoroscopy examinations.[10] Having been identified as a large contributor to collective dose to the population from radiological examinations,[11,12] this study investigated radiation doses received by patients referred for BaE examinations at three state hospitals in the Western Cape in SA with the aim of identifying potential DRLs. The relationship between the measured radiation doses and the patients’ mass, the fluoroscopy times, and use of conventional fluoroscopy or digital fluoroscopy units, were also investigated.

Materials and methodology
From June 2008 to May 2009, patient radiation dose measurements were performed at three state hospitals in the Western Cape. The radiation doses were measured using dose area product (DAP) meters that were permanently fitted onto the fluoroscopy units. The DAP meters were calibrated annually and also reset to zero for every new patient. Hospital 1 used a Philips conventional fluoroscopy (CF) unit that was operated by a radiologist with more than five years’ experience. Hospitals 2 and 3 employed digital fluoroscopy (DF) units of Mecall and Philips models respectively: these were operated by radiology registrars. Quality assurance of the equipment was ensured by ascertaining from the individual equipment records that the equipment had passed the quality control tests.

In order to set DRLs, radiation dose measurements should be obtained from at least 10 patients weighing 50-90 kg.[10] Ten adult patients between the ages of 18 to 85 years, from each of the three state hospitals, who were referred for BaE and weighed from 50 to 90 kg, were included in the study. The measurements were obtained from 10 consecutive patients at each site thereby reducing sampling bias and ensuring a sample that is representative of the population presenting at state hospitals in this region of South Africa. Permission to conduct the study was obtained from the head of department of each of the three radiology departments. Ethics approval was granted by the Cape Peninsula University of Technology.
The patients provided consent to be included in the study.

Results

DAP values
Radiation doses were measured on 30 adult patients with a respective mean age and mass of 58.3 years and 68.8 kg. The DAP values recorded at the three hospitals are shown in Table 1. Site 3 recorded the lowest third quartile DAP value (22.6 Gycm²). This DAP value was lower than the combined third quartile DAP (36.5 Gycm²) of the three sites.

DAP and patients’ mass
There was a weak linear correlation between patient mass and DAP value as shown in Figure 1 when the data from the three study sites were combined. The patient mass explained 30.45% (R²=0.3045; p=0.02) of the DAP variation. When the patient mass and DAP value correlation were individually considered for the three study sites, the patient mass explained 59.60% (site 1: R²=0.5960; p=0.009), 60.72% (site 2: R²=0.6072; p=0.008) and 38.15% (site 3: R²=0.3815; p=0.056) of the DAP variations as shown in Figures 2, 3 and 4 respectively. Distribution histograms of mass and DAP were plotted and showed a normal distribution of the data in Figures 5 and 6 respectively.

DAP and fluoroscopy time
There were no fluoroscopy times recorded at site 2 as the fluoroscopy unit indicated the time when a pulse of x-rays was activated and not the total fluoroscopy times (FT). The means and ranges for FT in minutes at sites 1 and 3 were 3.93 minutes (2.75 to 5.95 minutes) and 6.63 minutes (4.43 to 8.53 minutes) respectively. The combined mean fluoroscopy time was 5.28 minutes. Site 1 recorded a mean FT lower than the combined mean FT. There was no direct linear correlation between the DAP and FT with the FT explaining only 6.98% (R²=0.0698; p=0.261) of the variation in the DAP values as shown in Figure 7.

Discussion
The mean age of the patients was 58.3 years with a mean mass of 68.8 kg. The mean weight obtained in this study is within the 65 kg to 75 kg weight range recommended by the DWP (1992) from which DRLs are determined. Engel-Hills and Hering recorded mean age of 55.6 years and mean mass of 69.5 kg while investigating radiation doses for BaE in the Western Cape. The third quartile DAP value for BaE in this study was 36.5 Gycm² and this is therefore the recommended DRL for BaE in the Western Cape.

The trend to record lower DAP values in subsequent dosimetry studies in the same geographical location[14,15,16] owing to improved radiation protection procedures and installation of dose saving fluoroscopy equipment was observed in this work. There was a 56.5% (84 Gycm²) radiation dose reduction when compared with a previous study in SA.[13] The ability of the DAP meter to integrate the absorbed dose over the whole beam area for the total exposure to the patient and provide a single measurement for BaE dose[8] allows the exclusive use of DAP measurements with-

Table 1. The mean, standard deviations and third quartile values DAP (Gycm²) for BaE at the three study sites.

<table>
<thead>
<tr>
<th>Study site</th>
<th>Number of participants</th>
<th>Mean DAP (Gycm²)</th>
<th>STDEV DAP (Gycm²)</th>
<th>Third quartile DAP (Gycm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>29.0</td>
<td>7.6</td>
<td>33.6</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>39.4</td>
<td>10.4</td>
<td>50.4</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>17.9</td>
<td>9.7</td>
<td>22.6</td>
</tr>
<tr>
<td>Combined</td>
<td>30</td>
<td>28.7</td>
<td>12.7</td>
<td>36.5</td>
</tr>
</tbody>
</table>

Figure 1. DAP versus mass for all BaE patients.

Figure 2. DAP versus mass for BaE at site 1.
out converting them to effective dose. This saves the radiology personnel time converting DAP values to effective dose.

While clarifying the use and setting of DRLs, it was indicated that DRLs should not be used in a precise manner but rather as simple tests for identifying unusually high patient dose levels complementary to professional judgement. Additionally, DRLs should be easily measurable dose quantities above which equipment and procedures must be reviewed for radiation dose optimisation. Furthermore, when dose data are collected from one or two hospitals, it should be used to monitor local trends in patient dose in order to establish compliance to the recommended DRL.

**Patient mass**

Carroll and Brennan as well as Warren-Forward et al. found that patient mass contributed to 70% and 58% variation in DAP respectively. The study suggests that patient mass influences the DAP reading more at any individual site and fluoroscopy unit, compared to all sites averaged together. This can be seen by the R² that are higher for individual sites than for all the data grouped together. This may be attributed to the radiological findings during a BaE examination, which may require radiologists to adjust their technique, resulting in a higher or lower DAP reading. It may also be ascribed to the adoption of various screening techniques in the absence of a standard protocol applied at all the study sites, the level of experience of the radiologist performing the procedure as well as the variation in the patient population.

**Figure 3.** DAP versus mass for BaE at site 2.

**Figure 4.** DAP versus weight for BaE at site 3.

**Figure 5.** Distribution of mass of patients.

*Mean = 68.78; Std. Dev. = 9.824; N = 30*

**Figure 6.** Distribution of DAP.

*Mean = 28.72; Std. Dev. = 12.648; N = 30*
as dose saving capabilities of the equipment used. The employment of the same fluoroscopy unit for all BaE examinations at each study site may be responsible for change in the patient mass data affecting the DAP variation when the study sites were individually considered. The plotted histograms of mass (Figure 5) and DAP (Figure 6) showed a normal distribution. However, it is recommended that more data should be gathered in future studies to provide a more discerning distribution on the histogram.

Fluoroscopy time
Site 1 recorded a lower mean FT than site 3. The lower FT at site 1 was attributed to the radiologist, with more than 5 years’ experience performing BaE, in contrast to the registrars performing the procedures at site 3. Yakoumakis et al. found registrars to register FT of the order of 9.1 minutes compared to radiologists who recorded 3.2 minutes. Though the FT may be affected by the dynamic nature and findings of the examination, radiologists are capable of controlling the FT by modifying the technique used. Contrary to the lower FT being associated with a reduction in DAP, this was not observed in this study (Figure 7). This may be attributed to registrars operating the DF unit at site 3. The dose saving features of DF units allowed the registrars to record low DAP readings but high FT.

Digital versus conventional fluoroscopy units
Site 1 employed a CF unit while sites 2 and 3 employed DF units. Site 3 recorded a mean DAP value (17.9 Gycm$^2$) lower than those at site 1 (29 Gycm$^2$). The capacity of DF units to maintain lower doses than CF units was realised in this study. The radiology registrars, associated with long FT and high number of images, maintained lower mean DAP values using the DF unit compared with the radiologist with more than five years’ experience employing the CF unit. Broadhead et al. recorded dose savings of almost 50% with DF (13.88 Gycm$^2$) compared with CF (25.35 Gycm$^2$). Despite employing a DF unit with pulsed fluoroscopy capability and acquiring images at low mean frame rates of 7.5 pulses per second, associated with radiation dose saving, site 2 recorded a mean DAP 26.4% higher than site 1. This high DAP value may be attributed to the high mA ranges (82 mA to 150 mA) employed on DF units to compensate for the image noise arising from low frame rates. With high mA settings the resultant dose does not decrease by the same amount as the frame rate. Mahesh found a dose saving of 25% to 28% with a 50% decrease in frame rate. Such high mA settings, among other factors, such as registrars performing the BaE, may have caused the high DAP readings at site 2.

Conclusion
This paper discussed the radiation doses received by patients referred for BaE at three state hospitals in the Western Cape. The third quartile DAP value of 36.5 Gycm$^2$ was 56.5% lower than that obtained in an earlier study in the Western Cape. The patient mass was responsible for 30% of the DAP variation with data from all three study sites combined. There were no direct correlations between the FT and DAP. This was attributed to comparing radiology personnel with different levels of training using different types of equipment. The capacity of DF units to record lower radiation dose than CF units was realised, with radiology registrars (associated with long fluoroscopy times), maintaining lower mean DAP values on the DF unit compared with a radiologist with more than five years’ experience operating a CF unit.

Limitations of the study
This study was limited to three state hospitals. The sample size of this study was according to international recommendations for the calculation of a DRL on at least 10 participants of average mass 70 kg ± 5. A larger study would more conclusively determine the reasons for radiation dose variations measured.

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References


