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SHORT REPORT

DOSE-AREA PRODUCT MEASUREMENTS DURING BARIUM ENEMA RADIOGRAPH EXAMINATIONS — A WESTERN CAPE STUDY

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The aim of this study was to obtain a direct measurement of the typical dose delivered to an average adult patient during a barium enema examination. Measurement was done on a a sample of 50 patients at three departments, using a dose-area product (DAP) meter. The comparison of the results with UK median levels indicates that the doses measured in South Africa are higher (41 Gy cm^2 (dose × area) v. 48 Gy cm^2). Patient protection can be improved by comparing local practice with national reference levels. The values obtained in this study (first quartile 35 Gy cm^2, median 48 Gy cm^2, third quartile 84 Gy cm^2) are recommended as initial reference dose levels for barium enemas in South Africa.

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The barium enema is the radiological examination of choice if disease of the large bowel is suspected[1] and as such is a relatively frequent procedure in any radiology department. The barium enema allows for the physical examination of the entire colon and rectum and is minimally invasive. When performed with care this examination will provide satisfactory sensitivity and specificity for the detection of carcinoma and adenomatous polyps of more than a few millimetres in size.[2] The barium enema is a complex investigation, considered to be a high-dose procedure of significance when considering radiation dose to the patient or the population.[3]

The objective of this study was to obtain a direct measurement of the typical dose delivered to an average adult patient during a barium enema examination. Direct dose

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measurements of patients having the examination provide the best indication of the actual dose received. Patients vary physically and this means that the thickness and density of the part of the body being examined will influence the dose. In order for the dose measurements to be representative of routine practice and to be able to compare them with dose measurements from another institution or other norms, careful selection of the measurement sample is required. The average value of the doses measured on a representative sample of at least 10 patients per facility is considered to provide a good indication of typical clinical practice.[4]

MATERIALS, METHODS AND PATIENTS

The dose-area product (DAP) meter was selected as a suitable ionisation chamber for the measurement of dose received by the patient during a barium enema examination, since a DAP meter is well suited to measuring the dose to the patient for a complete examination involving screening and radiographs. The dose quantity is easily measured and is considered by some to be sufficient for checking and comparing the effectiveness of modifications to technique or equipment that are introduced to reduce patient dose.[5]

Information for each patient participating in the survey was recorded on a specially prepared data sheet. Male and female adult patients were selected and 50 patients were included in this group.

Patients were selected from two tertiary state institutions and one private practice in the Western Cape. The reasons for selecting these institutions were: (*i*) it was essential to measurements at more than one institution in order to establish a mean dose for barium enema examinations representative of a cross section of patients, techniques, equipment and operators; (*ii*) the three institutions permitted measurement on three distinctly varied equipment types; and (*iii*) the objective of using the measurements in order to establish a regional reference dose for the Western Cape for the barium enema examination would be met by involving these three institutions.

The mean values for mass for the barium enema patients (Table I) in the present study were within 5 kg of 70 kg.[6]

Incomplete examinations were excluded. Examinations that were prematurely terminated, for for whatever reason, were not included in the sample of measurements from which the average dose was calculated.[4]

The measurements were taken at the three institutions, using a unit where the barium enema radiograph examination is routinely performed. The measurements involved the use of the same DAP meter and data collector at all institutions. Data were recorded for all patients. The dose meter used for calibrating the DAP meter was a PTW Universal Dosemeter with a 0.6 cc ionisation chamber and reference source. This instrument is a secondary standard dose meter calibrated by the Council for Scientific and Industrial Research (CSIR).

The DAP meter used (NE Technology Ltd, type 2640A) measures the dose for the complete procedure, including repeat radiographs, in order to reflect the actual dose required to obtained a diagnostic result. The type 2642A (small) chamber was used at all three centres.[7]

In the case of centre A, there were two tubes and in order to record the dose for the complete examination the transmission chamber was moved between the two tubes during the procedure.

The DAP reading will not be a true indication of the surface dose administered to the patient unless the chamber is calibrated against the particular unit in use. Calibrations were done on each unit where measurements were taken in this study. The readings taken on the under-couch tube of centre A required a correction factor of 0.920. The readings from the other three sources did not require correction.

Centre A

This was a diagnostic radiograph unit with an under-table tube assembly and over-table spot-film device. There is also an overhead tube assembly and table assembly for standard radiography.

Table I. Patient number, age, mass, fluoroscopy time, total number of exposures and DAP for the three centres individually and combined

Centre	No. of patients	Mean age (yrs)	± SD	Mean mass (kg)	± SD	Mean fluoroscopy time (min)	± SD	Mean number of exposures	± SD	DAP ($Gy\ cm^2$)	± SD
A	10	44.8	17.2	63.9	10.4	3.4	1.5	15.1	2.0	99.7	21.3
B	10	56.8	13.9	81.0	10.2	5.9	1.6	18.2	2.7	56.6	24.6
C	30	58.8	14.5	67.5	11.3	6.6	5.3	12.8	1.8	51.9	32.2
Combined	50	55.6	15.6	69.5	12.2	5.8	4.3	14.3	2.9	62.4	34.1

SD = standard deviation; $Gy\ cm^2$ = dose × area.

Centre B

Centre B was a diagnostic radiograph unit with an over-table tube assembly. There are under-table cut-film cassettes for hard copy film sizes other than the large 35 cm × 43 cm film. The images taken during screening are recorded with the aid of an electronic photospot system which can be copied onto film as required.

Centre C

This was a universal diagnostic radiograph unit with over-table tube assembly and under-table spot-film device.

Technique factors

Screening kilovoltage (kV) and milliampere (mA) readings were recorded during the procedure, for all patients, in order to establish a realistic mean (Table II). A minimum of two readings were taken for any patient, that is the highest and lowest factors. Up to seven readings were recorded for some patients. The accumulated screening time, as indicated by the X-ray control, was recorded. Exposure factors of kV and milliampere seconds (mAs) were recorded accurately for all exposures during the examination.

Film size was recorded in all cases, and the total number of exposures. The beam projection for each exposure was recorded in all cases.

RESULTS AND DISCUSSION

Fluoroscopy time

Martin and Hunter[8] have stated that for barium enemas the contribution to mean dose from fluoroscopy and radiography varies significantly between different units, with the contribution from fluoroscopy ranging from 24% to 57%. Martin makes the statement that this is related to the fluoroscopy time. An estimate of the contribution to the mean dose from fluoroscopy in the present study results in values of 68% for A, 54% for B and 63% for C.

Total number of exposures

The total number of exposures in the present study ranged from 10 to 21. As the dose to the ovary is in the region of 0.002 Gy per exposure,[9] the effect of an increase in the total number of exposures can be considerable. The comment in the National Council on Radiation Protection and Measurements (NCRP-102) report[10] should be heeded by all doing a barium enema, namely that in procedures where spot film cameras are used and where multiple images are easily obtained, the radiologist must be fully aware of the manner in which exposures are made and must exercise great care to ensure that only the required exposures are made.[10]

Dose-area product

The DAP measurements in this study followed the trend of the National Radiological Protection Board (NRPB) survey[4] which showed a large variation in the distribution of DAP for barium enemas within the same centre and when comparing the centres involved in the survey (Table III). The lowest recorded dose was 15.7 Gy cm^2 (dose × area) and the highest was 162.4 Gy cm^2. The percentile calculations indicate that A has the highest median value followed by B and then C. The combined median is 48.2 Gy cm^2 and the range is shown by the maximum and minimum readings at each centre. The variation in the

Table II. Mean kV and mAs for AP, PA amd lateral projection

No. of patients	Mean AP (kV)	± SD	Mean AP (mAs)	± SD	Mean PA (mAs)	± SD	Mean PA (mAs)	± SD	Mean LAT (kV)	± SD	Mean LAT (mAs)	± SD
50	104	12.73	23.71	27.37	97	16.63	45.5	35.28	112	8.35	46.57	47.9

SD = standard deviation; AP = anteroposterior; PA = postero-anterior; LAT = lateral.

Table III. Results of DAP measurements (%)

Centre	Minimum measurement (Gy cm^2)	1st quartile measurement (Gy cm^2)	Median measurement (Gy cm^2)	3rd quartile measurement (Gy cm^2)	Maximum measurement (Gy cm^2)
A	83.3	84.1	88.4	109.3	139.5
B	24.4	40.5	62.9	64.7	108.3
C	15.7	32.4	40.9	66.5	162.4
Combined	15.7	34.6	48.2	84.3	162.4

mean DAP for the three units in this study is attributed to equipment differences. The older, under-couch unit with the lowest mean fluoroscopy time had the highest DAP measurement. Conversely, the equipment with digital capabilities had the longest mean fluoroscopy time but the lowest DAP measurement. This is in line with studies which show that digital equipment is capable of delivering lower doses than non-digital equipment.[11]

CONCLUSION

Optimisation of patient protection can be improved in diagnostic radiology by comparing local practice with reference levels of patient dose for a given examination.[5] The increased use of DAP meters in radiology departments would make it possible for dose information from diagnostic radiography to be recorded routinely. The dose could then be compared with standard reference doses in order to maintain optimum radiation protection.[12]

In South Africa there are no national reference doses. The measurements conducted for this study of barium enema examinations could serve as initial reference dose levels for this examination in this country. Importantly, though, the extensive work on reference doses that has been carried out in the UK can be used as a guideline. These reference doses were based on the NRPB survey conducted in the early 1980s.[3] These were adopted as the initial national dose standard for the UK and Europe.[12] The most recent NRPB R289 of 1996 indicates that the reference level, set from the rounded third quartile, is 33 Gy cm^2.[13] This could be considered the more appropriate reference level to aim for in South Africa. The reference doses for barium enemas in the UK and Western Cape, as calculated for this study, are given in Table IV.

Table IV. Reference doses for barium enema

Place	1st quartile (Gy cm^2)	Median (Gy cm^2)	3rd quartile (Gy cm^2)
UK[11]	26	41	60
Western Cape	35	48	84

Exceeding reference doses is considered to be an indication of poor practice and therefore requires immediate investigation.[14] Roberts has suggested that the median and quartile values are of greatest importance and that the median should be a readily achievable target dose as practices have improved over the last 9 years.[15] Roberts goes on to say that the third quartile value should possibly be the level above which an investigation should be undertaken to reduce the dose and that the first quartile value should also be an investigation level in order to evaluate that the image quality at this low dose is adequate for the diagnostic purpose.

Comparison with UK reference levels for this examination indicate that the combined doses measured during this study appear to be higher. Table III gives these results for centres A, B and C separately and the variation between these X-ray units is noticeable.

As the under-couch equipment in this study indicated that the doses are higher because of equipment factors rather than technique, it is advised that the reference doses be calculated for the type of equipment in order to make them more meaningful. The digital equipment in this study demonstrated higher median values than the standard overhead equipment. This is probably related to technique rather than the equipment and it is therefore considered appropriate to recommend similar values for all overhead equipment until such time as the digital equipment can be investigated more fully.

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