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ORIGINAL ARTICLE

A Survey of Patient Dose in Barium Enema Examination in a Hong Kong Public Hospital

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ABSTRACT

Objectives: *To determine the total dose-area product values for barium enema examinations; to determine the major dose contributor and to propose methods for reduction of patient dose without affecting the diagnostic values of the examination; and to compare the results with dose reference levels reported in the literature.*

Materials and Methods: *Radiation dose was measured in 33 patients involved in a pilot study. Radiography was found to be the major contributor to the patient dose during an average of 6.8 ± 2.4 radiographs per patient. In order to reduce patient dose, the screen-film combination was replaced with a faster and higher contrast combination. A survey of 422 barium enema examinations was then performed to evaluate the effect on dose reduction.*

Results: *Using the fast screen-film combination, the average radiographic dose-area product was significantly reduced ($p<0.001$). The observed mean dose-area product was 1711 ± 1360 cGycm^2 and the estimated effective dose was 4.96 ± 3.94 mSv.*

Conclusions: *The dose-area product value obtained with the fast screen-film combination is comparable to values reported by other researchers and complies with the dose reference levels proposed from relevant surveys in the United Kingdom and the Netherlands.*

Key Words: *Barium enema, Patient dose, Survey*

INTRODUCTION

In diagnostic radiology, optimisation of radiation protection requires periodic dose measurements as a means of comparing radiological techniques or X-ray equipment. According to the International Commission on Radiological Protection,[1] effective dose is the most appropriate quantity correlating to the risk from exposures during radiological procedures. The effective dose is derived from the weighted sum of the equivalent doses to 20 of the most radiosensitive tissues and organs of the body.

For simple radiographic and radiographic/fluoroscopic examinations, effective dose can be estimated by indirect methods, using the measured entrance skin dose (ESD) and the dose-area product (DAP).[2-5] To approximate the effective dose, the measured quantity is multiplied by accepted conversion factors determined through detailed analysis of each examination procedure.[6-8] Hence, dose assessment in diagnostic examinations has been simplified and reduced to a single measurement of DAP. For complex examinations, however, it is necessary to take into account that the patient orientation, fluoroscopic/radiographic parameters and the associated DAP readings are changing continuously throughout the examination.

Barium enema examination as a radiological procedure is of particular interest because it contributes substantially to the collective dose from medical diagnostic radiology. Objectives of the current study were:

- to determine the total DAP values fo barium enema examinations
- to determine the major dose contributor and to propose methods for reducing the effective dose during this procedure without affecting the diagnostic value of the examination

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Table 1. Typical radiography practice during barium enema examinations

Projection	Nominal kVp	HVL (mm Al)	SID (cm)	Nominal field size (cm x cm)	Mean DAP ($cGycm^2$)
Antero-posterior	85	3.16	115	46 x 36	351
Postero-anterior	85	3.16	115	46 x 36	292
Prone caudal	96	3.51	115	36 x 30	431
Lateral rectum	96	3.51	115	36 x 26	406
Right decubitus	85	3.16	115	43 x 38	620
Left decubitus	85	3.16	115	43 x 38	447
Postero-anterior erect	85	3.16	115	43 x 38	367

Abbreviations: kVp = tube potential; HVL = half value layer; SID = source to image distance; DAP = dose-area product.

- to compare results at the Tuen Mun Hospital with the dose reference levels (DRLs) derived from other similar surveys.[8,9]

MATERIALS AND METHODS

All barium enema examinations performed at the Tuen Mun Hospital utilise the same X-ray facilities (TRIDOROS 512MP, Siemens, Forchheim, Germany). This unit has two X-ray tubes (over-couch and under-couch) with a last image hold feature, but does not offer an option for dose selection. The tube potential (kVp) and the tube current (mA) are automatically adjusted by an automatic brightness control (ABC) during fluoroscopic procedures. For radiography, exposure can be made using either the under-couch tube or over-couch tube manually or through automatic exposure control (AEC).

A flat ionization chamber (Diamentor M4; Physikalisch-Technische Werkstatten, Freiburg, Germany) was mounted onto the collimator of each X-ray tube. This chamber encompassed the entire X-ray beam and therefore yielded a quantity, the DAP in units of $cGycm^2$, that was independent of the positioning of the patient in the X-ray beam.[10] As it is optically transparent, it does not adversely affect the light beam for positioning.

Calibration

Regular calibration and quality assurance checks were completed by the medical physics division. For the calibration, exposure rate was measured using an ionization chamber for a known X-ray field size at a known distance. Under the same conditions, DAP was measured and compared with the product of the measured exposure rate and the X-ray field size to generate a calibration factor. Since the calibration was performed in the same X-ray facilities as the barium enema studies, variation in DAP due to differing filtration was eliminated. However, the calibration factor can vary according to the applied potential and a calibration curve or table should be established to account for this variation.[10]

Table 2. Typical fluoroscopic practice during barium enema examinations. Note that the source to skin distance was 45 cm for all projections

Projection	Nominal kVp	HVL (mm Al)	Mean DAP ($cGycm^2$)
Left anterior oblique	85	3.17	59.1
Right anterior oblique	99	3.66	333
Left posterior oblique	85	3.17	569
Right posterior oblique	90	3.34	288
Antero-posterior	85	3.17	442
Postero-anterior	84	3.13	217
Left lateral	104	3.84	1706
Right lateral	106	3.91	387

Abbreviations: kVp = tube potential; HVL = half value layer; DAP = dose-area product.

Pilot Study

Detailed observations of techniques, exposure factors and DAP results were sampled among 33 randomly selected patients. Demographic data, body size measurements (antero-posterior thickness, right flank to left flank distance, distance from xiphoid process to symphysis pubis) were recorded. If the orientation of the patient was changed during fluoroscopy, then the fluoroscopic DAP, the screening time, and the average kVp values for that orientation were also recorded. For each radiograph, data including the applied kVp, field size, source to image distance (SID), and the radiographic DAP were noted.

Table 1 and Table 2 outline typical practice observed for radiography and fluoroscopy, respectively, during the barium enema examinations. The effective dose was not calculated during the examination as the pertinent software for this task was not available. Instead, a conversion factor of 0.0029 $mSv/cGycm^2$ (effective dose/DAP), proposed by other researchers,[7,8] was used as a first approximation to estimate the effective dose.

Radiography was found to be the major contributor to the patient dose with an average of 6.8 ± 2.4 radiographs taken per patient. Since the focusing regions of interest are relatively large in size with a coating of barium,

Table 3. Summary results including average number of radiographs taken, average screening times, and dose-area product values

	No. of		Dose-area product ($cGycm^2$)			Screening time (seconds)
	Patients	Radiographs	Fluoroscopy	Radiography	Total	
1	33	6.8 ± 2.4	1622 ± 1799	2570 ± 2404	4192 ± 3600	189 ± 141
2	422	No Record	1044 ± 1083	677 ± 579	1711 ± 1360	233 ± 172

1 Kodak X-Omatic regular screen, Fuji RX film, relative speed of 200.
2 Fuji HR-FAST screen, SUPER HR-G30 film, relative speed of 600.

Table 4. Comparison of age, screening times, and total dose area product for male and female patients — main study results

	Age (years)	Screening time (seconds)	Total dose-area product ($cGycm^2$)	No. of Patients
Male	48.1 ± 24.1	266 ± 208	1864 ± 1602	146
Female	50.1 ± 19.7	221 ± 156	1621 ± 1192	276

the diagnostic value of the image is not greatly affected by an increase in quantum mottle. Thus, the original screen-film combination (Kodak X-Omatic regular screen - Fuji RX film, relative speed of 200) was replaced by a faster and higher contrast combination (Fuji HR-FAST screen, SUPER HR-G30 film, relative speed of 600). A total of 422 barium enema examinations were subsequently performed with this fast screen-film combination to evaluate the effect on dose reduction.

RESULTS

Table 3 summarises the results of both the pilot and main studies. Radiography was the major contributor to patient radiation dose during barium enema examinations. For the pilot study, the average radiographic DAP was 2570 ± 2404 $cGycm^2$ per patient. This was about 1.6 times greater than the contribution from fluoroscopy (1622 ± 1799 $cGycm^2$). By using the fast screen-film combination, the average radiographic DAP was significantly reduced (677 ± 579 $cGycm^2$, $p<0.001$, two-tailed t-test). There were no statistically significant differences in either the average fluoroscopic DAP or the average screening time with the screen-film combination replacement.

There were 276 female and 146 male patients involved in the main study. The average age was approximately 50 years for both the female and the male patients (Table 4). There were no statistically significant differences in the DAP readings (i.e. total DAP and screening time) between the two patient groups, and their approximate average effective dose was 4.96 ± 3.94 mSv.

DISCUSSION

Identification of the major contributor to dose delivery is the first step in achieving dose reductions. In this

Table 5. Comparison of dose-area product in the literature with Tuen Mun Hospital results

	X-ray equipment used	Screen-film relative speed	Dose-area product ($cGycm^2$)
Calzado et al[3]	NA	NA	4889 ± 443
Hart and Wall	IGE MVP80	400	2022 ± 576
	Philips Super 80CP	400	1031 ± 407
Geleijns et al[8]	Philips Diagnost 92	400	2900 (average)
	Philips Diagnost 96	Digital	
	Philips Diagnost 66	Digital	
	Siemens Pantoscop 5	100mm film	
	Siemens Pantoscop 5	400	
	GE Advantx	Digital	
	Philips Diagnost 90	200	
	Philips Diagnost 92	400	
	Siemens Siregraph CF	Digital	
	Philips Multi Diagnost 3	Digital	
IPSM[9]	NA	NA	4100
Yakoumakis et al[11]	CGR (GE) Prestilix 1600	400	3720
	Siemens Gigantos 1012E	400	3320
Shrimpton et al[12]	NA	NA	4186 ± 58
Results in this study	Siemens Tridoros 512MP	200	4192 ± 3600
		600	1711 ± 1360

Abbreviations: IPSM = Institute of Physical Sciences in Medicine; NA = not available.

study, radiographic dose was found to contribute a substantial portion of the radiation dose to patients. This may be the reason why screen-film combination with a relative speed of at least 400 has been recommended.[8] The screen-film combination replacement, with a relative speed of 600, resulted in a marked dose reduction (74%) without any degradation of image quality. There is no doubt that both image quality and patient dose during barium enema examinations depend on many interrelated parameters. These include not only the range of equipment (X-ray generator, image intensifier, TV display), but also the ability of patients to cooperate, and other variables in the clinical situation. However, remarkable agreement in the effective dose/ dose-area product conversion factor between centres with differing X-ray facilities and techniques has been reported.[7,8] The conversion factor of 0.0029 $cGycm^2$ was used in this study and estimated the average effective dose of 4.96 ± 3.94 mSv for barium enema examinations performed at this centre.

In 1992, the National Radiological Protection Board (NRPB) set the dose reference levels (DRLs) for barium enema at 6000 $cGycm^2$.[9] Recently, a value of 4000 $cGycm^2$ has been proposed.[8] As shown in Table 5, the average dose area product from this study is comparable to the values reported by other researchers and the recommended DRLs.[3,7-9,11,12]

It should be highlighted, however, that the DRLs should not be viewed as dose limits or an indication of optimum performance. For example, confident exclusion of pathology in physiological cases may require thorough investigation, leading to a DAP higher than the DRLs. In contrast, the examination procedure can be very short if the pathology is obvious. Thus, the DRLs can help to identify those examinations, which require investigation of their excessively high doses. Based on the results of this study, use of a DRL value of 4000 $cGycm^2$ for this purpose appears appropriate.

CONCLUSION

The major source of radiation dose in barium enema examination is radiography and reduction can be effectively achieved by using a fast screen-film combination. Based on an evaluation of 422 barium enemas, the DAP readings (i.e. average dose-area product and screening time) for female and male patients were comparable. DAP for barium enema performed in our centre is comparable with the values reported by other researchers. The average effective dose for barium enema performed at Tuen Mun Hospital is 4.96 mSv and findings indicate that use of a dose reference level of 4000 $cGycm^2$ is appropriate in clinical practice.

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