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A survey of patient doses from selected fluoroscopically guided interventional procedures at Pietersburg Provincial Hospital

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Abstract

Aim: The aim of this study was to analyse DAP records of some fluoroscopically guided procedures performed at Pietersburg Provincial Hospital to determine the average DAP per examination, as well as to deduce inter-operator variabilities, and to compare DAP values with reference values from literature.

Method: DAP records captured over the period May 2014 to March 2015 were retrieved and analysed. The average DAP and screening time per examination was determined. For barium swallow and voiding cystourethrogram examinations the mean DAP values and screening times per lead operator were determined and variation in these values was determined by calculating the coefficient of variation of mean DAPs and screening times.

Results: Average DAPs and screening times were 30.2Gy·cm², 40s for HSG; 48.7Gy·cm², 54s for cystogram; 28.8Gy·cm², 23s for IVP; 8.3Gy·cm², 130s for loopogram; 17.7Gy·cm², 53s for fistulogram; 50.6Gy·cm², 67s for VCU, 19.5Gy·cm², 67s for barium swallow; 35.1Gy·cm², 121s for barium meal; 44.4Gy·cm², 124s for barium enema. The coefficients of variation for voiding cystourethrogram (VCU) were 59% DAP, 64% screening time and 16% DAP, 49% screening time for barium swallow.

Conclusion: DAP values for five examinations were comparable to reference values obtained from a similar study conducted at Charlotte Maxeke Academic Hospital, South Africa. DAP values for the remaining studies were higher than reference values. This, together with a high coefficient of variation for VCU, demonstrated that an opportunity existed for further dose optimisation.

Keywords

Dose area product, dose reference level, fluoroscopy

Introduction

Fluoroscopic procedures are inherently high dose because they have the potential to impart a patient radiation doses amounting to tens and hundreds of milli Sieverts.[1] There are recorded incidences where patients received cumulative doses of up to 3Gy resulting in severe deterministic effects manifesting as dermal necrosis.[2] These have become case studies in texts and academia on how not to perform fluoroscopic studies. Although they represent the extreme end of the spectrum of deterministic effects, records also exist of less severe effects resulting from lower doses. These doses still exceeded the threshold to cause observable effects.[2] For fluoroscopy the most important deterministic effect is skin injury; the severity depends on the magnitude of the radiation dose. The higher the dose the more extreme the severity. Stochastic effects are also a concern as they are in all medical exposures.

To eliminate the risks of deterministic effects, and minimise those of stochastic effects in a patient, fluoroscopic procedures must be carried out following the tenets of radiation protection in medical exposures. To implement justification and optimisation, it is preferable to consider whether alternative non-ionising radiation options could be used in a patient; if not then the benefits must outweigh inherent risks.[3] Once a decision has been made to continue with the procedure radiation doses must be optimised. This involves taking steps that ensure information can be obtained from resulting images with minimal patient dose.[4] The approach to optimisation is multipronged, involving quality control, adopting practises that reduce patient dose, establishment of dose reference levels (DRL), and conducting dose surveys. Of relevance to this report are DRLs and dose surveys. In radiographic imaging DRLs are defined as typical dose levels that are expected for standard sized patients when good medical practise is followed.[5] They are expected not to be exceeded while at the same time not to be considered as dose limits. It is only when DRLs are consistently exceeded that an investigation and possible review of local procedures are warranted, unless the excess doses can be justified clinically.[6] The process of accurately determining radiation dose imparted to a patient is not trivial, but is performed only when necessary. In lieu of radiation dose, dose indices, which are easier to measure and from which the former may be derived, are used to provide an indication of dose magnitude. Some dose indices have units of radiation dose, others do not. In general however the magnitude of a dose index is proportional to radiation dose. In fluoroscopy dose area product (DAP) is most commonly utilised to indicate dose and express dose reference levels. Measurement of DAP is accomplished with a DAP meter: a transmission type ionisation chamber that is positioned between the x-ray tube and the subject, usually attached to the anterior end of the beam-limiting device. A DAP meter may be independent or integrated with the imaging unit. It is a regulatory requirement in South Africa for all fixed fluoroscopy units manufactured after June 2006 to have a DAP meter installed.[7] Centres that conduct fluoroscopically guided interventional procedures are required also by regulation to establish local DRLs for certain examinations within a year of assuming procedures, and to review them every three years.[7] The International Commission on Radiation Units and Measurements (ICRU) Report 60, and the International Atomic Energy Agency (IAEA) Basic Safety Standards (BSS), recommend that DRLs be established nationally for the most common examinations performed in radiographic imaging, at the very least.[6] Dosimetry data are first collected at a centre level and then collated with that from several other centres to obtain a national dose reference level, located at the 75th percentile.[8] A centre-wide dose survey provides an opportunity to collect data that could potentially contribute towards the establishment of a national DRL. It also serves to inform centres of the magnitude of inter-operator variabilities, departures of dose indices from reference levels, and whether possibilities for further dose optimisation and patient dose reduction exist.

Aims

The aim of this study was to retrospectively analyse recorded DAP values for fluoroscopic examinations performed at Pietersburg Provincial Hospital radiology department. In particular the objectives were

- to collect DAP values for all fluoroscopic procedures performed at the radiology department,
- to determine the mean DAP values and screening time of each examination,
- to compare mean DAP for each examination with reference values obtained from literature,
- to determine inter-operator variations.

Material and Method

Fluoroscopic procedures at Pietersburg Hospital are performed on a Stephanix D2R3; an over-couch fixed screening unit commissioned in 2010. The unit is equipped with an integrated DAP meter, and an amorphous silicon flat panel detector capable of an all-digital imaging modality. There is a maintenance and quality assurance contract in place, which ensures that regular maintenance, quality control testing and calibration, are performed. Calibration of the DAP meter is done following the protocol described in the IAEA technical document (TECDOC) 1423.[10] As a regulatory requirement, DAP and screening time values for fluoroscopy procedures must be recorded, along with the respective name of the patient, examination, radiographer and radiologist. These records are entered manually in a file in the fluoroscopy room by the operator at the study site

For this study the data were retrieved and entered in a Microsoft ExcelTM spreadsheet. A separate worksheet was created for each examination and the exam-specific data were captured. Data for barium enema, barium meal, barium swallow, cystogram, fistulogram, and voiding cystourethrogram (VCU) were analysed. It is inevitable that data entered manually might not be captured correctly in its entirety and some incorrect entries would appear as outliers. To identify outliers, DAP values were normalised to screening times and subjected to the modified Thompson Tau test. Outliers were removed from the data. The average DAP and screening times for each examination were determined, along with the range and individually compared to reference values.

For those examinations with larger sample sizes, namely barium swallow and VCU, inter-operator variations were determined by calculating the coeficient of variation in the mean DAPs per lead operator.

Results

The sample comprised 138 patients who were referred for nine different fluoroscopy examinations: barium meal, barium swallow, barium enema, cystogram, VCU, loopogram, intravenous pyelogram (IVP), hyterosalpingography (HSG), and fistilogram. Three entries were removed for being outliers or having been illegible. Records suggested the majority of patients were referred for VCU (38%), followed by barium swallow (31%). Figure 1 illustrates the distribution of these cases. The average DAP and screening time are given in Table 1 along with reference values from literature, where available. Inter-operator variabilities for barium swallow and VCU expressed as the coefficient of variation of average DAP and screening time are shown in Table 2. Inter-operator variability could not be reliably determined for the remaining studies because of low frequencies. VCU examinations at the study site are led by radiologist/registrar while

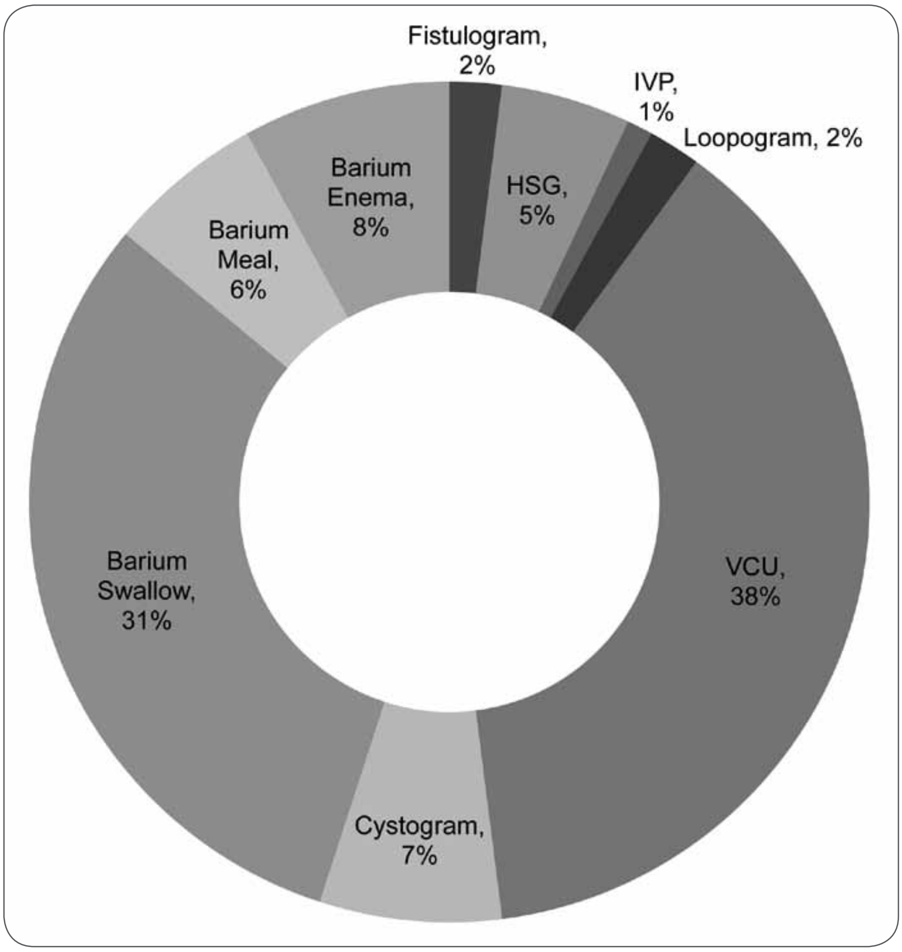

Figure 1. Distribution of cases referred for fluoroscopy examinations at Pietersburg Provincial Hospital.

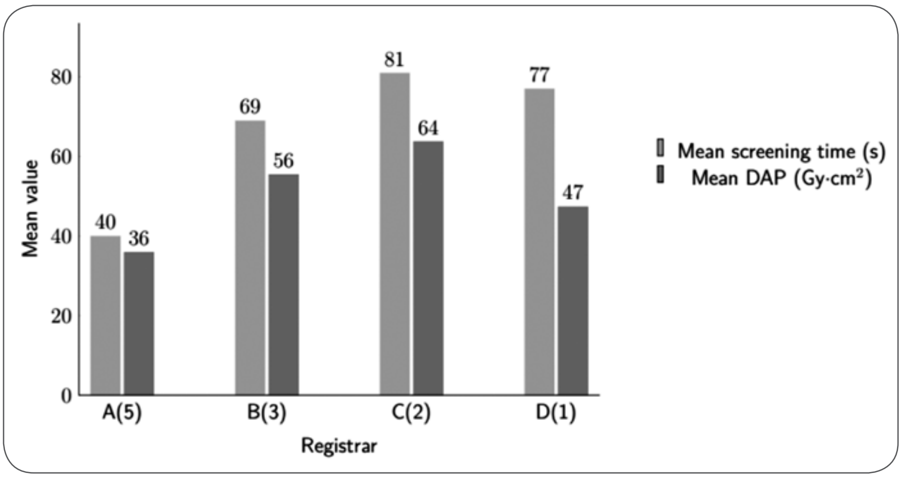

Figure 2. Mean DAP and screening time per registrar leading VCU.

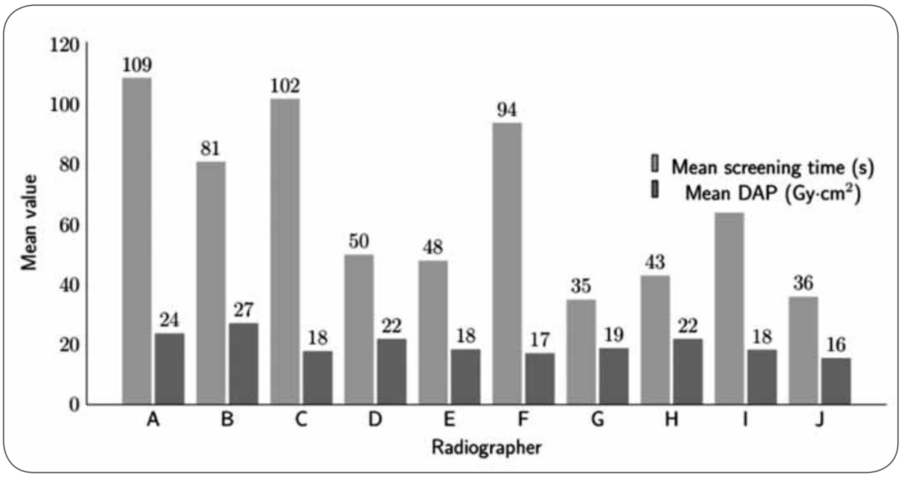

Figure 3. Mean DAP and screening time per radiographer leading barium swallow.

barium swallows are generally radiographer led. As such Table 2 shows variabilities of these two healthcare practitioners. Figure 2 illustrates the mean DAP and screening times for VCU per registrar as a bar graph. Each registrar's experience expressed as number of years is indicated in brackets. A similar illustration is in Figure 3 showing the mean DAP and screening times per radiographer for the barium swallow examination.

Discussion

The average DAP readings for all, except four examinations, compared well with reference values obtained in literature. It is also worth noting that the majority of these reference values were obtained from a study conducted at a radiology department in a neighbouring province with a similar patient demographic profile.[9] In particular the average DAP reading for barium swallow was below the 23.2Gy·cm^2 average from a major study undertaken by the International Atomic Energy Agency.[10] After observing that three examinations (VCU, HSG, and IVP) were associated with DAP values that were excessively higher than reference, the author individually interviewed a radiographer with at least three years' experience post qualification and a senior radiographer with at least ten years' experience post qualification employed at the study site radiology department. Both had rotated through fluoroscopy several times and made the following statements.

- The majority of the doctors in the department were junior and senior registrars. There were only two radiologists available.
- The registrars received minimal supervision during procedures.
- Patient dose was not optimised during these procedures as a result of inexperience and absence of supervision of the registrars.

Figure 2 appears to suggest a relationship between experience of the registrar and magnitude of the screening time and DAP: the more experienced the registrar the less the observed values of DAP and Time. There appears to be a contradiction with registrar D with about a year of experience and averaging DAP values only exceeded by registrar A. It was discovered that for many instances of this procedure, and over the period under observation, registrar D was mentored by experienced registrar A. It was not possible to repeat this investigation for HSG and IVP because of insufficient data.

There appeared to be more consistency amongst radiographers as demonstrated by the reduced inter-operator variability of DAP for the barium swallow examination compared to that of registrars for the VCU examination. Coefficient of variation in DAP was only 16.7% as shown on Table 2. Figure 3 shows that all radiographers averaged DAP values that were either slightly above or below 20Gy·cm^2, with the majority being below.

It must be noted that although average DAP values for some procedures at the study site were above reference values, the resulting skin doses were below threshold levels for deterministic effects. For instance, the highest observed DAP in this study was 186.4Gy·cm^2 for a cystography examination. Using conversion factors developed by the National Council on Radiation Protection and Measurements and available from the International Atomic Energy Agency[11] the estimated maximum resulting effective dose would have been 33.6mSv. This value is below the minimum threshold of 2000mSv for observable deterministic effects, i.e. early transient skin erythema.[12] Because of the nature of the procedure this dose would have been to multiple fields thereby further reducing both the dose per field and the associated risk of deterministic effects. Having said that, there still exists the probability of inducing stochastic effects which are not associated with dose thresholds, but whose probability of occurrence increases with dose. As such any potential to reduce radiation dose must be fully utilised as it would in turn minimise this probability.

The fact that some DAP values and screening times were above reference values, and that significant inter-operator variations were observed, suggests that room for further dose optimisation exists.

Table 1. Average DAP values and screening times for fluoroscopy examinations under review.

EXAMINATION	FREQUENCY	THIS STUDY		REFERENCE	
		Time (s)	DAP (Gy·cm²)	DAP (Gy·cm²)	Time (s)
HSG	7	40	30.2	4.3[9]	-[1]
Cystogram	9	54	48.7	10[9]	-[1]
IVP	2	23	28.8	10.2[10]	-[1]
Loopogram	2	130	8.3	8.1[11]	120[11]
Fistulogram	3	53	17.7	12.2[11]	240[11]
VCU	50	67	50.6	15.6[11]	240[11]
Barium swallow	41	67	19.5	19.1[11]	240[11]
Barium meal	8	121	35.1	23.4[11]	420[11]
Barium enema	11	124	44.4	50.6[11]	600[11]

[1] "-" means reference values were not available

Table 2. Range and coefficient of variation of DAP and screening times amongst registrars for VCU and radiographers for barium swallow.

EXAMINATION	RANGE		COEFFICIENT OF VARIATION	
	DAP (Gy·cm²)	Range of T (s)	DAP (%)	T (%)
VCU	11 - 105	23 - 205	59	64
Barium swallow	16 - 27	35 - 136	16	49

Methods to achieve this are elaborated extensively in literature.[13] Lack of supervision of registrars by a radiologist, be it an oversight or otherwise, must be rectified promptly to avert the occurrence of radiation incidents and accidents. Due to the nature of their training radiographers are taught to appreciate the value of radiation protection early and they might be more knowledgeable than registrars in that regard. Registrars must therefore not hesitate to consult them when in doubt. Optimisation is a process of balancing patient dose and image quality, and DRLs are an important guidance of the optimum patient dose. Image quality must not be compromised by the quest to minimise dose by attempting to strictly comply with DRLs, as they are not static. DRLs may be exceeded provided that clinical justification exists. When DRLs are exceeded consistently however, an investigation is called for. Such an investigation may find a need to either improve clinical practise or update the DRLs.

Conclusion

Records of DAP and screening times for selected fluoroscopy examinations performed at Pietersburg Hospital were analysed retrospectively. For each examination the mean DAP and screening time was determined and compared to reference values found in literature. Inter-operator variations for the two most common procedures were determined. Most of the average DAP values in this study compared well with reference values. Where values were higher some remedial action was suggested.

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