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Evaluation Of Dose Area Product, Entrance Surface Dose and Fluoroscopic Time in RGU/MCUG Examination

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ABSTRACT

Introduction: The evaluation of radiation dose in diagnostic imaging is crucial for optimizing patient safety and maintaining image quality. In retrograde urethrogram (RGU) and micturating cystourethrogram (MCUG) examinations, Dose Area Product (DAP), Entrance Surface Dose (ESD), and Fluoroscopic time (FT) serve as indicators of radiation exposure. This study aims to assess these parameters to better understand radiation exposure levels during RGU/MCUG procedures.

Methods: In this quantitative cross-sectional study, a total of 107 male patients who underwent RGU/MCUG examinations at Tribhuvan University Teaching Hospital (TUTH) from May 1st to July 31st, 2024, using the Siemens Healthineers Luminos dRF Max digital fluoroscopy system, were included. We employed a purposive, non-probability sampling method to select the participants for the research. The displayed DAP, ESD, and FT were evaluated.

Results: We found that the average mean values for DAP, ESD, and FT were 5384.43 ± 5343.98µGym^2 (53.84 ± 53.44 Gycm2), 98.01±94.49 mGy, and FT of 2.98 ± 1.70 mins, respectively. A very strong positive correlation was found between cumulative DAP and Total ESD ($r=0.983$, $p<0.05$).

Conclusions: Our study found a strong, statistically significant correlation between cumulative DAP and Total ESD, highlighting a direct relationship between these measures. These findings emphasize the importance of monitoring DAP and FT in clinical settings to optimize radiation exposure and procedural efficiency.

Keywords: *Diagnostic Imaging; Patient Safety; Universities*

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INTRODUCTION

Retrograde Urethrogram (RGU) and Micturating Cystourethrogram (MCUG) are specialized fluoroscopic radiological procedures commonly employed to evaluate the anatomy and function of the urinary tract. These procedures involve exposure to ionizing radiation, raising concerns about patient safety and the potential long-term risks associated with radiation exposure.1

The evaluation of radiation dose in fluoroscopic examinations is crucial for minimizing risks and ensuring that doses remain within recommended safety limits. Key parameters in assessing radiation exposure include Dose Area Product (DAP), Entrance Surface Dose (ESD), and Fluoroscopic Time (FT). Understanding these parameters is essential for optimizing procedural protocols, improving patient safety, and adhering to the principles of radiation protection, such as ALARA (As Low As Reasonably Achievable).2

Dose Area Product (DAP) or Kerma Area Product (KAP) is a method of radiation dose monitoring used in radiographic and fluoroscopic studies. It indicates the radiation dose received by a patient, which quantifies the overall radiation dose absorbed by the patient. The dose area product is linked to a patient's stochastic risk. Entrance Surface Dose (ESD), also called Entrance Skin Dose, is the measure of the radiation dose that is absorbed by the skin as it reaches the patient. Fluoroscopy Time (FT) indicates the duration of continuous X-ray exposure during the procedure, influencing patient radiation exposure.3,4

Monitoring DAP and ESD helps ensure that radiation exposure remains within acceptable limits to minimize the radiation risk. Prolonged fluoroscopy time can increase the overall radiation dose delivered to the patient. Monitoring and minimizing fluoroscopy time help reduce radiation exposure and associated risk. This study aimed to evaluate the DAP, ESD, and FT in RGU and MCUG examinations. We tried to find correlations among these parameters and between them and the patient's age. Through this investigation, we also hope to provide insights that could inform future guidelines for radiation dose management in urological imaging.

METHODS

Methodology

This quantitative, cross-sectional study was conducted in the Radiology Department of Tribhuvan University Teaching Hospital (TUTH) from May to July 2024.

From a previous study, r = 0.45 (according to Lazarus MS et al., the DAP versus FT relationship for all the examined patients resulted in a correlation r = 0.45)11

Estimated effect size = 0.45

For a 99% confidence level Z_(α/2)=1.96

Z_β= 2.33 (for 99% power)

The minimum sample size was derived from the following formula:

$$\text{sampling size (n)} = \frac{(Z_{\alpha/2} + Z_{\beta})^2}{(\text{estmited effect size})^2}$$

$$= \frac{(1.96+2.33)^2 / 0.45^2}{}$$

$$= 4.29^2/0.45^2$$

$$= 18.4041/0.2025$$

$$= 90.88$$

A total of 107 RGU/MCUG examinations during the study period that met the inclusion criteria were included in the study. Ethical approval was obtained from the Institutional Review Committee (IRC) of the Institute of Medicine (IOM) before data collection. Data was collected after obtaining verbal and written informed consent from the patients.

The inclusion criteria consisted of male patients (aged 14 years or older) referred for RGU/MCUG examinations to the Radiology Department at TUTH. The Luminos dRF Max digital fluoroscopy system was used to collect the data. The Dose Area Product (DAP), Entrance Surface Dose (ESD), and Fluoroscopic Time (FT) were noted after the completion of each examination.

Statistical analysis

The data obtained were tabulated in an Excel worksheet and analyzed statistically by using the IBM SPSS software. We performed the Kolmogorov-Smirnov and Shapiro-Wilk tests to assess whether the data were normally distributed. The result indicated that the data were not normally distributed ($p<0.001$), so we analyzed the data using non-parametric statistical methods, that is, by using Spearman's correlation test.

RESULTS

Tests of Normality

The Kolmogorov-Smirnov and Shapiro-Wilk tests were applied for normality of distribution, and they showed a significant difference from normal distribution. Hence, we found that the distribution of the cumulative dose area product was not normally distributed.

Descriptive analysis

The mean, median, and standard deviation of 107 patients who had undergone RGU/MCUG examination are shown in Table 1. Among 107 male patients, the age group with the highest number of patients undergoing the RGU/MCUG examination was the 65-75 years age group (25 patients), followed by the 45-54 years age group and the 25-34 years age group, respectively. There were only 6 patients above the age of 75 years.

The average DAP and ESD values were found to be 5384.43 ± 5343.98 µGym² (53.84 ± 53.44 Gycm²) and 98.01 ± 94.49 mGy, with average mean FT 2.98 ± 1.70 min for RGU/MCUG examination, respectively. (Table1)

Table 1: Statistical description of included data set

	Mean	Median	Std. Deviation
CUMULATIVE DAP (Gycm²)	53.84	3294.82	53.44
TOTAL ESD (mGy)	98.01	61.40	94.49
TOTAL FT (min)	2.98	2.44	1.70

Age and cumulative DAP

We found that there was a weak positive correlation between the age of the patients and DAP ($r=0.047$), and this correlation was not statistically significant (p-value=0.628).(Table2)

Table 2: Spearman's corrleation between age of the patients and cumulative DAP

	CUMULATIVE DAP	
Age of patient	P value	Spearman's rho (r)
	0.628	0.047

AGE and Total FT

We found a weak negative correlation between the age of the patients and FT ($r=-0.115$) and this correlation was not statistically significant (p-value=0.238). (Table3)

Table 3: Spearman's corrleation between age of patients and total fluoroscopic time

	TOTAL FLUOROSCOPIC TIME	
Age of patient	P value	Spearman's rho (r)
	0.238	-0.115

Cumulative DAP and Total ESD

Our study showed a very strong positive correlation between cumulative DAP and Total ESD($r=0.983$), and this correlation was statistically significant (p-value<0.001), which suggests that there was a very strong relation between the cumulative DAP and Total ESD. The strong correlation suggests that cumulative DAP was a strong predictor of total ESD.(Table 4) (Figure1)

Table 4: Spearman's corrleation between cumulative dose area product and total entrance surface dose

	TOTAL ENTRANCE SURFACE DOSE	
Cumulative DAP	P value	Spearman's rho (r)
	0.000	0.983

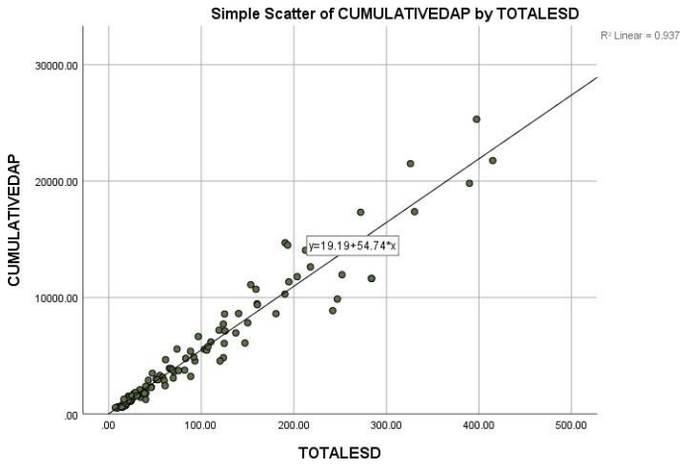

Figure 1: Scatter plot diagram of total entrance surface dose with cumulative dose area product

Cumulative DAP and Total FT

We found a weak positive correlation between Cumulative DAP and Total FT (r=0.202) this correlation was statistically significant (p-value=0.037). (Table 5)(Figure 2)

Table 5: Spearman's corrleation between cumulative dose area product and total fluoroscopic time

	TOTAL FLUOROSCOPIC TIME	
Cumulative DAP	P value	Spearman's rho (r)
	0.037	0.202

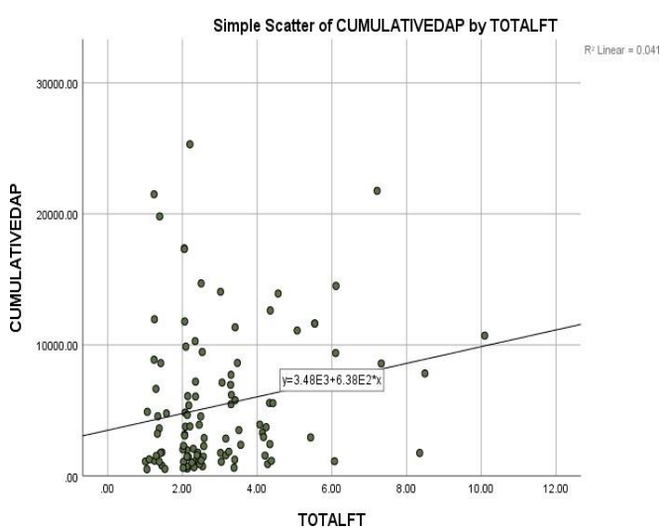

Figure 2: Scatter plot diagram of total FT with cumulative DAP

Total ESD and Total FT

We found a weak positive correlation between Total ESD and Total FT (r=0.187). This correlation was not statistically significant (p-value=0.54), which suggests that there was a weak and non-significant positive relation between the Total ESD and Total FT, which indicates that Total FT is not a strong predictor of Total ESD. (Table 6)

Table 6: Spearman's Correlation Between Cumulative Dose, AREA PRODUCT, and Total Fluoroscopic Time

	TOTAL FLUOROSCOPIC TIME	
TOTAL ENTRANCE SURFACE DOSE	P value	Spearman's rho (r)
	0.54	0.187

DISCUSSION

Retrograde Urethrogram (RGU) and Micturating Cystourethrogram (MCUG) are specialized fluoroscopic radiological procedures that use ionizing radiation to evaluate the lower urinary tract. The radiation dose evaluation is a critical aspect of radiological examinations, particularly in procedures like fluoroscopy, where patients are exposed to ionizing radiation. The DAP, ESD, and FT are the crucial parameters that play an important role in monitoring the radiation doses received by the patient and help us to ensure patient safety by minimizing radiation dose while still achieving diagnostic-quality images. RGU/MCUG is one of the most common fluoroscopic examinations performed in our hospital.[5,6]

Dose area product (DAP) is a product of the surface area of the patient that is exposed to radiation at the skin entrance multiplied by the radiation dose at this surface. Measurement of dose area product is suitable for achieving the optimum degree of safety during radiological examination of the patient. DAP is a valuable radiation dose descriptor because radiation-induced bioeffects are directly related to both the magnitude of the radiation dose and the total amount of tissue that is irradiated.[7]

The average DAP was 53.84 ± 53.44 $Gycm^2$. This value was very high compared to a study by Wambani JS et al. who reported a mean KAP of 10 $Gycm^2$. The values reported here are also much higher compared to the National Reference level of the UK (7 $Gycm^2$).These findings are alarming and raise concerns about patient as well as operator safety. Furthermore, the lack of an available local Diagnostic Reference Level makes it difficult to interpret these findings meaningfully. We found a very high standard deviation of 53.44 $Gycm^2$. This signifies a high variability in the DAP values in different patients. This may partly be attributed to the fact that we are a teaching hospital with frequent student rotations. Thus, individual skill may have contributed to this wide variance in the measured total DAP.[7,8.,9]

We observed a mean fluoroscopy time of 2.98 ± 1.7 minutes. This was slightly higher than the study by Wambani JS et al. who reported a mean fluoroscopy time of 2.4 minutes. The fluoroscopy time was also greater than the Diagnostic Reference Level given by Hart D et al. (1.6 minutes).[8,9]

DAP and ESD

Our analysis revealed a strong positive correlation between DAP and ESD (r = 0.983, p-value < 0.001), indicating that as DAP increases, ESD also increases in a highly predictable manner. This suggests a significant relationship between these two variables, implying that DAP can be a reliable predictor of ESD within the context of RGU/MCUG. This finding aligns with previous studies done by Chida et al. that suggested a close association between these parameters in similar experimental setups.[10]

Age with DAP and FT

The correlation between Age and DAP was found to be weak and non-significant (r=0.047, p-value=0.63). This indicates that Age does not have a strong or statistically significant impact on DAP, suggesting that the variations in DAP are independent of the Age factor in our study population. One possible explanation for this lack of correlation could be that the physiological or technical factors influencing DAP are not Age-dependent, or that the Age range in our sample was not broad enough to detect an effect. In contrast, the study done by Mathew et al. showed a statistically significant strong correlation (r=0.71, p<0.001) between Age and DAP.[11]

Similarly, the correlation between Age and Fluorotime was weak (r=-0.16, p-value=0.24), indicating no significant relationship between these variables. This suggests that Age does not meaningfully influence fluoroscopic time, reinforcing the idea that Age may not be a critical factor in the performance of fluoroscopic time measurements within our experimental design.

DAP and FT

A significant but weak positive correlation was found between DAP and Fluoroscopic time (r=0.202, p-value=0.037) however, the studies performed by Mathew et al. showed a moderate correlation between DAP and Fluoroscopic time (r=0.45 and p-value<0.001). This result highlights the need for further exploration of the factors that contribute to fluoroscopic time and how it relates to DAP.[11]

ESD and FT

The correlation between ESD and Fluorotime was weak and non-significant (r=0.19, p-value=0.54). This result suggests that ESD does not have a meaningful relationship with fluoroscopic time within the parameters of our study. This non-significant result might indicate that ESD and fluoroscopic time measure different aspects of the experimental setup, or that other variables not included in this study could influence their relationship. However, the study performed by Chida et al. found a strong correlation (r=0.801) between ESD and fluoroscopic time; the correlation was also statistically significant (p-value<0.001).[10]

CONCLUSION

The mean DAP and Fluoroscopy time observed in our study was higher than the Diagnostic Reference Levels demonstrated in the literature. This is alarming and should alert the responsible authorities. We also found a significant, strong positive correlation between DAP and ESD.

CONFLICT OF INTEREST

None

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None

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