ESTABLISHMENT OF TYPICAL DOSE VALUE FOR INTERVENTIONAL RADIOLOGY EXAMINATION IN RADIOLOGY DEPARTMENT, HOSPITAL PENGAJAR UPM

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ABSTRACT: Angiography is commonly used as a diagnostic imaging tool for diagnosing and treating the patient from simple to complex examination. Despite the advancement in imaging technologies, the radiation dose to the patient remains a concern when using this procedure. Diagnostic Reference Levels (DRLs) are used to identify the amount of dose exposed to the patient and monitor the high dose received by an individual in a specified radiological procedure. The aim of this study is to establish Institutional Diagnostic Reference Levels (DRLs) based on median data dose distribution for cerebral examination (cerebral angiography and stroke thrombectomy) and compared with established Malaysian National Diagnostic Reference Levels (MNDRLs). The Dose Area Product (DAP) and fluoroscopy time were recorded using clinical data from the participating modality from 1 January 2022 until 31 December 2022 at Teaching Hospital Universiti Putra Malaysia (HPUPM). The data collected for each procedure with a minimum recommended number of patients (at least 30) required to propose a DRL for each examination type within the data collection period. The mean value, standard deviation, median value, and third quartile were calculated using Microsoft Excel Version 2013. The Typical Dose Value for the interventional procedure was defined as the median of the distribution of DRL quantities and required further optimization. The distribution of DAP values for the cerebral angiogram and stroke thrombectomy ranged between 5.05 mGy.m^2 to 31.80 mGy.m^2 and 7.03 mGy.m^2 to 43.23 mGy.m^2 respectively. The institutional DRLs for cerebral

angiogram (10.60 mGy.m^2) and stroke thrombectomy (21.80 mGy.m^2) were higher than the established MNDRL. From the findings, stroke thrombectomy examinations recorded the highest Typical Dose value follow by cerebral angiogram examination. Generally, the factors that can affect DRL values are a patient-related factor, equipment-related factor, the complexity of the procedures, operator's experience in handling the machine and interventional radiologist experience that can contribute to various results.

KEYWORDS: *Typical Dose Value Diagnostic Reference Level (DRL); Radiation Dosage; Interventional Radiology; Cerebral Procedure, Dose Management*

1.0 INTRODUCTION

Interventional Radiology (IR) is a non-invasive technique that evolved in various fields of medicine including diagnostic and therapeutic procedures for numerous diseases. The use of IR in the Radiology Department tends to increase significant radiation exposure and there is a possibility of increased radiation risks to both patients and staff. According to the Internal Commission of Radiological Protection (ICRP), the absorbed dose threshold for the brain and lens of the eye is as low as 0.5 Gy and the patients could exceed the threshold of tissue reaction when the procedure is very complex and take longer duration time [1]. Therefore, the concern in tissue reaction when the maximum dose of patients reached above the threshold value should be an emphasis on optimisation of unnecessary radiation as well as preventing skin erythema or epilation, cataract and severity of the deterministic effect.

Radiation dose given to patients can be high or low depending on the type of examination, patient size and different techniques used by radiographers and radiologist during interventional procedures. The lack of experience radiologist in interventional procedures might be an important factor affecting increasing fluoroscopic time and patient radiation dose. With the recent advanced technologies, the availability of dose monitoring devices to keep track of patient dosimetric data with numerous parameters used in different modalities and dose management in this facility plays a pivotal role in improving the patient dosage including proper training of fluoroscopic operator and

use various of dose reduction techniques [2].

Diagnostic Reference Level (DRL) is an indicator used to identify the dose to the patient is unusually high or low in a specified radiological procedure for medical imaging equipment [3]. DRLs were determined through the 75th percentile of the distribution of median value and act as a guide for monitoring dose to individual patients meanwhile Typical Dose Value was determined by the median value of the distribution of the DRL quantity, as there are insufficient data to use the third quartile hence require further optimization. Therefore, DRL is not a dose limit, but as a tool for dose optimizations during diagnostic procedures [4]. The ICRP indicates that DRLs are recommended by professional organizations to measure the dose distribution among patients and for local review if regularly exceeded. They recommend considering DRLs as much as possible during all procedures using radiation because the cumulative fluoroscopy exposure time is a poor metric of patient radiation dose [5].

The establishment of DRL is relatively common in simple examinations such as radiographic procedures. In interventional guided examinations, DRLs only applied in the management of patient doses to ensure patient doses are as low as reasonably achievable (ALARA) to avoid unnecessary stochastic effects [6]. However, for complex procedures involving fluoroscopy or CT examinations, establishing a DRL is quite difficult due to the multiple images taken and fluoroscopy time leading to a wide range of DAP dose distribution in different procedures. As a consequence, DRLs are required to evaluate patient dose and as a guided protocol in monitoring exceeding radiation dose.

This work focuses on the establishment of Typical Dose Values for interventional examination. Kerma Area Product (KAP) or Dose Area Product (DAP) is the required primary DRL quantity. DAP is a useful parameter to correlate well using total energy given to a patient, which is associated with the effective dose, therefore to overall cancer risk. The Typical Dose value for interventional procedures is established on the median of local distributions which are then compared with the established MNDRL [7][8]. MNDRL and Typical Dose Value should be

set for each examination or procedure for each clinical indication to provide investigation levels for uncommon practices.

This study aimed to prospectively collect patient radiation doses and help to contribute to facility DRL for common cerebral procedures using the angiography system in the radiology department at HPUPM.

2.0 MATERIALS AND METHODS

2.1 Patient Dose Data

Patient data were collected from 1 January 2022 until 31 December 2022 from the Angiography console (Philips Allura Xper FD20/15) in Radiology Department, HPUPM equipped with a dose tracking system that indicates Diagnostic Reference quantities that have been proposed in Interventional radiology procedures. Dose monitoring devices usually keep track of Total air Kerma-Area Product (PKa,r), Total Dose Area Product (DAP), Total Fluoroscopy Time (FT), Total Number of Images (NI) and type of protocol procedures used. All these quantities represent dosimetric information where PKa,r relates to the effective dose given by accumulated exposure and exhibits subsequent stochastic effect [9][10]. Dose information for each patient was provided in the form of total DAP radiation dose metric and total fluoroscopy time was recorded.

2.2 Data Preparation

A total of 160 patients who participated in this study were cruited having met the following inclusion criteria of all fluoroscopic procedures listed in Guidelines on Malaysian DRLs in Medical Imaging (Radiology). However, two exclusion criteria were not included in this study since there is no Malaysian DRLs value of fluoroscopic procedures on patients below 16 years old and examinations done with fluoroscopy equipment that does not have KAP meter. The subjects were divided into two types of procedures; 129 cerebral angiogram and 31 stroke thrombectomy respectively with minimum recommended number of patients (at least 30) required to propose a DRL for each examination type within the data collection period, based on the recommendation from the ICRP Publication 135

[11]. The data was further analysed to determine the typical dose value and DRLs obtained from total DAP values.

2.3 DRL Calculation and Analysis

The total Dose Area Product (mGy.m^2) and total fluoroscopy time from the dose monitoring device were studied. All the data were analyzed to determine mean value, standard deviation, first quartile, median and third quartile using Microsoft Excel 2013 Version. The results of the data were presented in descriptive statistics of box plots and graphs. The median calculation obtained from the software for two types of interventional procedure represents a typical dose value to be established in Radiology Department, HPUPM. Meanwhile, the third quartile was used for the comparison with internationally established MNDRL. The use of DRL concept and quantities as optimization tools in our facility and was highly recommended by ICRP to reduce the dose as well as prevent unnecessary radiation to patients [12].

3.0 RESULTS AND DISCUSSION

The establishment of Typical Dose Value as a part of DRLs in interventional radiology was discussed further in this section. The DRL is classified according to the examination conducted on an individual obtained from median data known as the Typical Dose Value in data dose distribution. The established MNDRL in our country for cerebral examination (type of procedure not specified) was 8.7 mGy.m^2 and this value has not been revived for over ten years since 2013 [13]. DRLs in our institution have not been established yet and this study presented DRLs for two common procedures in our hospital. The Typical Dose Value contributed significantly to the goal of optimization of radiation doses and required further optimization.

A total of 160 Interventional procedures involving two different cerebral examinations: 129 cerebral angiogram (80.63%) and 31 stroke thrombectomy (19.38%) were collected. The most frequently performed in Interventional Radiology procedures were cerebral angiogram, stroke thrombectomy, cerebral aneurysm, central venogram, central venoplasty, fistulogram, right arthrogram, shoulder arthrogram, antegrade stenting, nephrostomy and permanent catheter. However, a minimum of 30 cases per examination were analyzed in

this study.

Table 1 presents descriptive statistics for the DRL quantities (mean value, standard deviations, median value and 75th percentile) for cerebral angiogram and stroke thrombectomy respectively. Figure 1 presents (in the form of box plots) the distribution of each DRL quantity (DAP and fluoroscopy time) for both cerebral procedures. Figures 2 and 3 present the Typical Dose Value, 75th Percentile and established MNDRL.

The distribution of DAP values (Figure 1) for cerebral angiogram and stroke thrombectomy were ranged between 5.05 mGy.m² (min) to 31.80 mGy.m² (max) and 7.03 mGy.m² (min) to 43.23 mGy.m² (max) respectively. On the other hand, the distribution of fluoroscopy time ranged between 3.14 minutes (min) to 52.42 minutes (max) and 5.10 minutes (min) to 117.02 minutes (max) respectively. From the results, Stroke Thrombectomy was the one that delivered the highest doses to patients and required the highest fluoroscopy times. The relatively high dose received by the patient in interventional procedure due to the complexity of examination and the total number of images taken. The observation of the complexity of cases could be due to different radiologist experience with the different techniques used during the procedure. In addition, high fluoroscopy time may be elucidated by the use low of pulse-rate fluoroscopy. Meanwhile, the elevated number of images taken could be the inconsistency in the interpretation of these specific images by radiologist and require further investigation in specific cases.

Table 1: Descriptive Statistics and Typical Dose Value for Cerebral Examination

DRL Quantities	Total DAP (mGy.m²)			Total Fluoroscopy Time (min)		
	Mean (SD)	Median	75th Percentile	Mean (SD)	Median	75th Percentile
Cerebral Angiogram	11.26 (4.17)	10.60	13.10	14.89 (10.23)	11.21	19.30
Stroke Thrombectomy	21.41 (6.48)	21.80	24.30	42.41 (22.45)	40.07	52.38

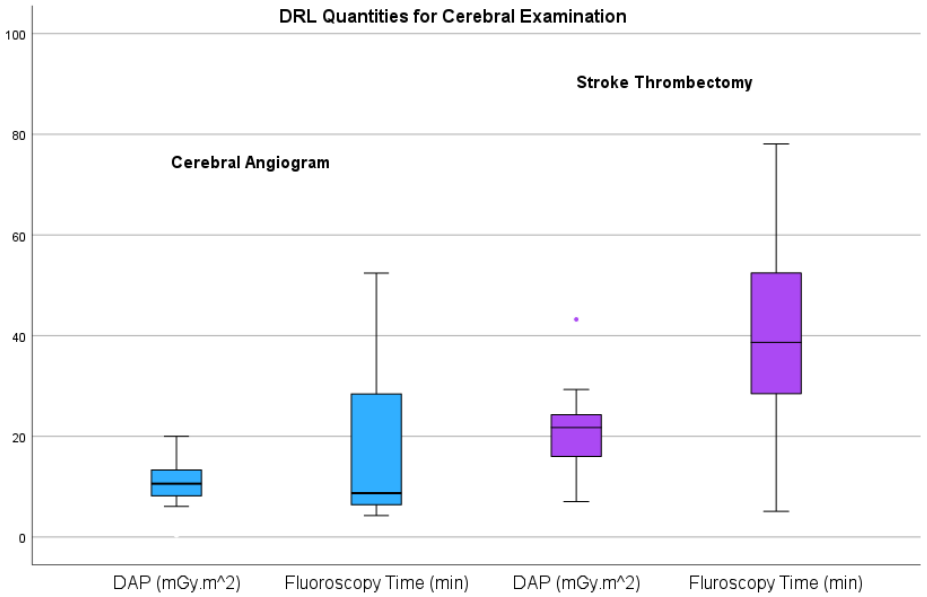

Figure 1: Box Plots of The Distributions of each DRL Quantities

Figures 2 and 3 show the Typical Dose Value (based on median values), 75th Percentile and Established MNDRL (based on dose summation of a single region) for both cerebral angiogram and stroke thrombectomy. The findings, show that the Typical Dose Value for cerebral angiogram (10.60 mGy.m^2) and stroke thrombectomy (21.80 mGy.m^2) are higher than the national DRL. Since the MNDRL was not revived yet, we are now using Typical Dose Value in our hospital for both cerebral procedures. Generally, the factors that can be affect DRL values are patient age, weight, scanning time, efficiency of the equipment and the operator's experience in handling the machine that can contribute to various effects.

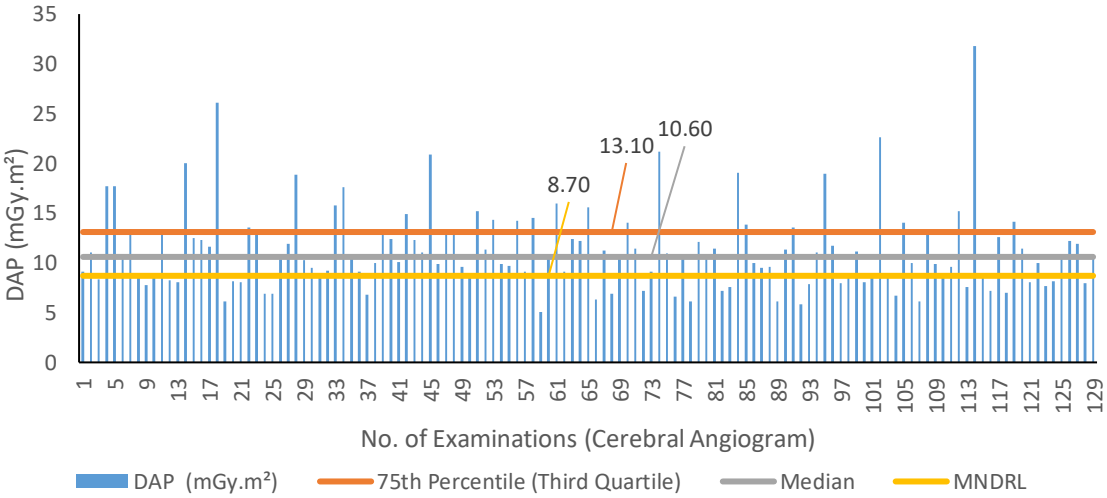

Figure 2: The Typical Dose Value (Median), 75th Percentile and MNDRL for Cerebral Angiogram

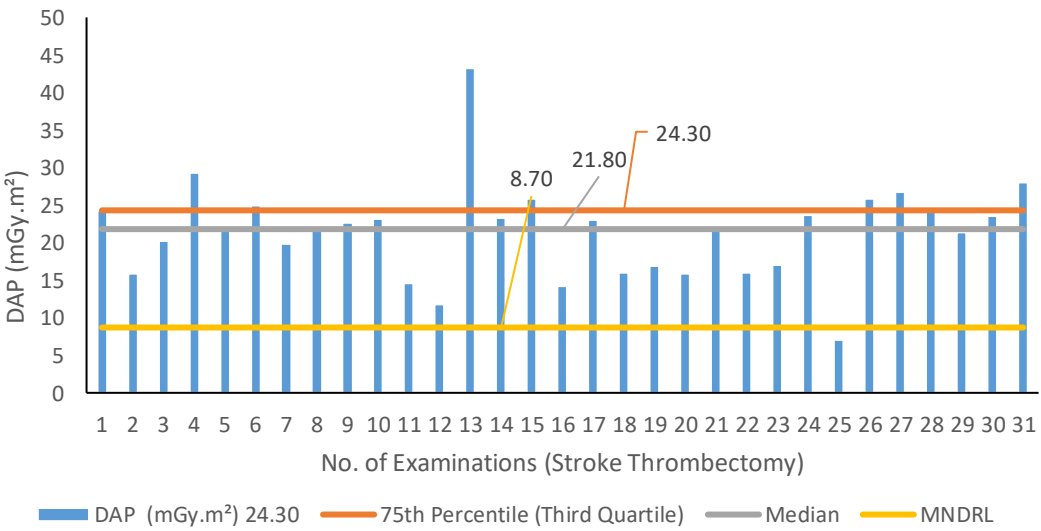

Figure 3: The Typical Dose Value (Median), 75th Percentile and MNDRL for Stroke Thrombectomy

4.0 CONCLUSION

Institutional DRLs were established using the median value for two types of examination (cerebral angiogram and stroke thrombectomy). The typical dose value for cerebral angiogram and stroke thrombectomy was 10.60 mGy.m^2 and 21.80 mGy.m^2 respectively. The Typical Dose value was higher than the established MNDRL. The complexity of the procedure was found in stroke thrombectomy where the patient dose was relatively high which can cause tissue reaction when the dose reaches a threshold value. The concept of As Low as Reasonably Achievable (ALARA) and dose management should be implemented in this hospital without affecting the image quality.

5.0 ACKNOWLEDGMENTS

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6.0 REFERENCES

[1] Boal, T. J., & Pinak, M. (2015). Dose limits to the lens of the eye: International basic safety standards and related guidance. *Annals of the ICRP*, *44*, 112–117.

[2] Mahadevappa, M. (2001). Fluoroscopy: Patient radiation exposure issues. RadioGraphics. Vol 21 Issues 4 (1022-1045)

[3] International Atomic Energy Agency. (2017, August 1). Radiation Protection in Fluoroscopy.

[4] Erskine J. Brendan, Zoe Brady & Elissa M. Marshall. (2014). Local Diagnostic Reference Levels for Angiographic and Fluoroscopic Procedures: Australian Practice. *Australas Phys Eng Sci Med.* 37:75-82.

[5] Hayashi, S., Takenaka, M., Hosono, M., Kogure, H., Hasatani. (2021). Diagnostic reference levels for fluoroscopy-guided gastrointestinal procedures in Japan from the rex-gi study: A nationwide multicentre prospective observational study. *SSRN Electronic Journal*.

[6] International Atomic Energy Agency. (2014). Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards. *IAEA*

Safety Standards Series No. GSR Part 3.

[7] International Atomic Energy Agency. (2017, August 7). *Radiation doses in interventional procedures*. IAEA. Retrieved January 28, 2023, from https://www.iaea.org/resources/rpop/health-professionals/interventional-procedures/radiation-doses-in-interventional-fluoroscopy

[8] Bleeser, F., Hoornaert, M.-T., Smans, K., Struelens, L., Buls, N., Berus, D., Clerinx, P., Hambach, L., Malchair, F., & Bosmans, H. (2008). Diagnostic reference levels in angiography and Interventional Radiology: A Belgian multi-centre study. *Radiation Protection Dosimetry*, *129*(1-3), 50–55.

[9] Tsapaki, V. (2020). Radiation dose optimization in Diagnostic and interventional radiology: Current issues and future perspectives. *Physica Medica*, *79*, 16–21.

[10] Papanastasiou, E., Protopsaltis, A., Finitsis, S., Hatzidakis, A., Prassopoulos, P., & Siountas, A. (2021). Institutional diagnostic reference levels and peak skin doses in selected diagnostic and therapeutic interventional radiology procedures. *Physica Medica*, *89*, 63–71.

[11] Vañó, E., Miller, D. L., Martin, C. J., Rehani, M. M., Kang, K., Rosenstein, M., Ortiz-López, P., Mattsson, S., Padovani, R., & Rogers , A. (2017). ICRP publication 135: Diagnostic Reference Levels in medical imaging. *Annals of the ICRP*, *46*(1), 1–144.

[12] International Commission on Radiological Protection. (2017). Diagnostic Reference Levels in Medical Imaging. Vol 46. No 1. ISSN 0146-645.Ministry of Health. 2013. Malaysian Diagnostic Reference Levels in Medical Imaging (Radiology). Radiation Health and Safety Section.

[13] Ministry of Health. (2013). Malaysian Diagnostic Reference Levels in Medical Imaging (Radiology). Radiation Health and Safety Section.