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***I. Garba, *A.Z. Abdurrazzaq, *A. Dare, ^A.M. Tabari, ^A. Ismail, #N.O. Egbe**

*Department of Medical Radiography & ^Department of Radiology Bayero University Kano, Kano State, Nigeria and #Department of Radiography, University of Calabar, Nigeria

**Corresponding Author**: I. Garba: igarba.radg@buk.edu.ng

# DOSIMETRIC AUDIT OF DIAGNOSTIC AND THERAPEUTIC ANGIOGRAPHIC PROCEDURES AT AMINU KANO TEACHING HOSPITAL KANO NIGERIA

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*Department of Medical Radiography & ^Department of Radiology Bayero University Kano, Kano State, Nigeria and #Department of Radiography, University of Calabar, Nigeria

**Corresponding Author**: I. Garba: igarba.radg@buk.edu.ng

**ABSTRACT**:
Angiography is the gold standard for the diagnosis and treatment of vascular and related diseases. However, the challenges and peculiarities of the procedure may result in increased fluoroscopy time and number of acquired images, which increased personnel and patients' radiation exposure. This study determines the dose area product readings following diagnostic and interventional angiographic procedures in an attempt to establish reference values for patient radiation dose optimization. This retrospective study reviewed the cases of 25 patients that were managed at the teaching hospital. Types of angiographic procedure, exposure parameters as well as radiation dose parameters were documented. Fluoroscopy time, number of frames acquired for each examination, fluoroscopy and frame radiation doses were equally recorded. Of the 25 patients, 6 were for 4-vessel cerebral Digital Subtraction Angiography (DSA), 3 for both lower limbs DSA, 4 for both lower limbs DSA and angioplasty, 3 for Inferior Vena Cava (IVC) filter placement, 2 for pulmonary arteriography, 2 for renal artery embolisation, and 5 for unilateral lower limb DSA and angioplasty. Renal artery embolization had the highest fluoroscopy and frame radiation doses (73764 cGy.cm2 and 4090 mGy) compared to others. Measured Dose Area Product (DAP) doses were above the Diagnostic Reference levels (DRLs) available in the literature thereby necessitating the need for radiation dose optimization through, continuous dose management.

**Keywords**: Angiography; Interventional radiology; fluoroscopy, Radiation doses

## INTRODUCTION:

Angiography is the gold standard technique for the diagnosis and treatment of vascular and related diseases [1]. The main application of angiography includes: stenotic vascular disease, aneurysms, emboli, occlusive disease, and thrombosis. The challenges and peculiarities of the procedure may result in increased fluoroscopy time and number of the acquired images. This may potentially increase the radiation dose both to the patient and personnel involved during the procedure.

However, if the protocols are optimized, the diagnostic information required from the procedure may be obtained at minimum possible radiation dose to the patient [1].

Radiation absorbed dose is the total amount of ionizing radiation absorbed by a material or tissues. It is expressed in Gray (Gy) upon exposure. Exposure may be defined as the total electrical charge per unit mass that x rays and gamma ray photon generate in dry air at standard temperature and pressure [2].

During angiographic procedures, the radiologists performing the examination stay close to the radiation field, and therefore can be exposed to scattered radiation from the patient and leakage radiation from the X-ray housing tube. Depending on the magnitude of fluoroscopy time, such exposure can be sufficiently high to cause some deterministic effects. In general, the radiation dose per examination is low, but nevertheless, the accumulated radiation dose might become significant over several years [3]. The Food and Drug Administration (FDA) of the United States of America has reported cases where radio-induced skin injuries, such as peeling or skin necrosis, have been observed due to prolonged X-ray irradiation of patients during interventional radiology procedures [4]. Some recommendations, like establishing protocols for each procedure, and determining the radiation dose rates for fluoroscopy systems to reduce the potential of radiation-induced skin injuries of patients have been suggested [4]

More recently, according to the Royal College of Radiology, the number of interventional radiology examinations has increased by more than 50% from 2007 to 2009 in the United Kingdom [5]. However, there are no published data available for the local population in Nigeria. Therapeutic interventional procedures performed for vascular anomalies such as aneurisms, arterio-venous malformations and arterio-venous fistulas, patients are often exposed to substantial amounts of radiation associated with the use of fluoroscopic imaging [4]. Therefore, the Euratom 97/43 directive introduced the obligation to evaluate radiation doses involved in "high-dose procedures", including those of interventional radiology [6].

Quantities that can be used as radiation absorbed dose parameters are: Entrance Skin Dose ESD in (mGy), and Dose Area Product (DAP) in (Gy.cm2), number of images associated with screening time or effective radiation dose. The most frequently used quantity for measuring radiation output during angiography is DAP (Gy.cm2) reading and it is used for setting DRLs [3].

In Nigeria at the moment, no study has been conducted to assess the radiation dose during angiographic examinations or DRLs established as a tool for radiation dose optimization. Therefore, performing radiation dose survey will be of practical importance in protecting both the patients and the personnel working in the angiography environment against unintended radiation exposure. The aim of this study was to determine the DAP values of different angiographic procedures at the Aminu Kano Teaching Hospital (AKTH), which is one of the only three hospitals in the Nigeria with a functioning catheter laboratory at the time of the commencement of this study.

**SUBJECTS AND METHODS**:

The study population consisted of all patients referred for Angiographic procedures (diagnostic and/or therapeutic) at the study site. Only data of patients that had angiographic examinations (diagnostic and therapeutic) with complete dosimetry records of fluoroscopy time and radiation dose values were included. Those with incomplete record were excluded. Ethical clearance was sought and obtained from the research ethics board of the AKTH.

The study was retrospective, cross-sectional and quantitative in design carried out at the AKTH in the densely-populated city of Kano, located in north-western Nigeria. The angiographic procedures were performed using digital single-plane Innova-3100 General Electric angiography imaging system equipped with flat panel detector. Our medical physicist checked the equipment six monthly for scheduled quality control tests, however no record of such tests was kept. Tube warm up is daily performed by the radiographer before procedure commences as instructed by the medical physicist. All procedures were performed by the board-certified radiologists, co-assisted by the radiographers. Information recorded on the data spreadsheet include: demographic data (age, weight and gender), clinical indications, type of angiography performed, radiation exposure parameters (kV and mAs), and DAP readings (fluoroscopy dose, cumulative radiation dose, fluoroscopy time, total radiation dose of acquired frames and number of frames) for each procedure.

The DAP meter used in our angiography machine has the following specification: model XTP8100G. The DAP meter information was obtained from the display console of the angiography machine. The acquired data was analysed using statistical package for social science (SPSS) version 20. The means, Standard deviation, ranges and percentages were calculated and recorded.

**RESULTS**:

The study involved 25 patients, consisting of 15 males (60%) and 10 females (40%). The age of the patients ranged from 15 – 81 years with mean and (±Standard Deviation) of 51.4 ±21.1 years. Their mean weight was 61.1±9.8 Kg. The range of angiography procedures performed during the review period included: 4-vessel cerebral DSA 24%, both lower limbs DSA 12%, both lower limbs DSA and angioplasty 16%, IVC filter placement for prevention of pulmonary thrombo-embolism (either through the jugular or femoral routes) 12%, pulmonary arteriography (with or without thrombolysis of pulmonary thrombus) 8%, renal artery embolism in advanced renal cell carcinoma 8%, and unilateral lower limb DSA and angioplasty 20%.

Table 1: Fluorodose parameters for diagnostic and therapeutic angiography procedures

| Procedures | No. of Patients | kVp Mean ±SD (Range) | mA Mean ± SD (Range) | Time (min) Mean ± SD (Range) | DAP in cGy.cm2 Mean ± SD (Range) |
|---|---|---|---|---|---|
| 4-Vessel cerebral DSA | 6 | 84±0.0 (84 - 84) | 4±3 (1 - 9) | 41±30 (12-77) | 27610±10098 (11141-41179) |
| Both lower limb DSA and angioplasty | 4 | 83±2 (80 - 84) | 1±1 (0.5-3) | 37±24 (15-70) | 23876±16864 (6648-39671) |
| IVC Filter Placement | 3 | 83±2 (80-84) | 16±9 (5-22) | 4±3 (2-8) | 7426±6859 (1991-15133) |
| Unilateral lower limb right or left DSA and angioplasty | 5 | 80±5 (74-84) | 1±0.6 (0.5-2) | 30±27 (5-76) | 27236.6±36250 (1952-89206) |
| Renal artery Embolization | 2 | 85±1 (84-85) | 5±2 (4-7) | 50±51 (13-86) | 73764±77182 (19188-128340) |
| Both lower limb DSA | 3 | 80±7 (72-84) | 3±4 (0.5-8) | 29±20 (11-50) | 19455±13838 (5728-33401) |
| Pulmonary arteriography | 2 | 84±0.0 (84-84) | 7±1 (6-7) | 18±2 (17-20) | 27443±3459 (24997-29889) |

Table 2: Frame radiation dose parameters for diagnostic and therapeutic angiography procedures

| Procedures | No. of patients | kVp Mean ± SD (Range) | mA Mean ± SD (Range) | Dose in mGy Mean ± SD (Range) |
|---|---|---|---|---|
| 4-Vessel cerebral DSA | 6 | 73±6 (67-82) | 158±18 (146-175) | 1611±598 (605-2888) |
| Both lower limbs DSA and angioplasty | 4 | 69±3 (67-72) | 150±9 (146-163) | 1891±1412 (559-3303) |
| IVC Filter Placement | 3 | 83±8 (74-88) | 161±12 (153-175) | 530±466 (146-1048) |
| Single lower limb right or left DSA and angioplasty | 5 | 71±8 (66-85) | 149±6 (142-155) | 2243±3132 (168-7769) |
| Renal artery Embolization | 2 | 75±4 (72-78) | 171±5 (167-174) | 4090±4397 (981-7199) |
| Both lower limbs DSA | 3 | 73±11 (67-86) | 150±8 (146-159) | 1093±626 (398-1613) |
| Pulmonary arteriography | 2 | 74±1 (73-75) | 176±1 (175-176) | 1544±156 (1433-1654) |

Table 3: Radiation dose values of the present study compared to the values established in the literature

| Procedure | Reference | No. of Patients | Fluoro time (min) Mean (Range) | DAP in cGy.cm2 Mean (Range) | Dose in mGy Mean(Range) |
|---|---|---|---|---|---|
| **4-Vessel cerebral DSA** | This study | 6 | 41.1 (11.6-76.5) | 27610.2 (11141-41179) | 1610.7 (605-2888) |
| | Ercole et al.[7] | 100 | 9.89 (1-48) | 1422.1 (330-5233) | |
| | Korir et al.[8] | 51 | 32.2 (12.3-65.5) | 1970 (50-9780) | 517 (57-1259) |
| **Both lower limb DSA and Angioplasty** | This study | 4 | 36.8 (15.1-69.8) | 23875.7 (6648-39671) | 1891 (559-3303) |
| | Marshall et al.[9] | 500 | 30.4 (14.5-55) | 2488 (219-2771) | |
| **IVC Filter Placement** | This study | 3 | 4.0 (1.7-7.9) | 7426 (1991-15133) | 530 (146-1048) |
| | Korir et al.[8] | 1 | 5 | 1890 | 41 |
| **Single lower limb right or left DSA and angioplasty** | This study | 5 | 30.4 (4.5-75.5) | 27236.6 (1952-89206) | 2243 (168-7769) |
| | Marshal et al.[9] | 500 | 30.4 (14.5-55) | 2488 (219-2771) | |
| **Renal artery Embolization** | This study | 2 | 49.5 (13.3-85.6) | 73764 (19188-128340) | 4090 (981-7199) |
| | Korir et al.[8] | 8 | 11 (4-29) | 1577 (380-5695) | 540 (103-1798) |
| **Both lower limb DSA** | This study | 3 | 29.3 (10.9-50.3) | 19455 (5728-33401) | 1093 (398-1613) |
| | Korir et al.[8] | 34 | 9 (3-48) | 850 (110-3980) | 283 (57-1259) |
| **Pulmonary arteriography** | This study | 2 | 18.4 (16.9-19.9) | 27443 (24997-29889) | 1543 (1433-1654) |
| | Korir et al.[8] | 4 | 15.5 (11-16.8) | 3440 (666-6311) | 322 (82-617) |

Table 1 shows the descriptive analysis of the fluoroscopy exposure parameters, time and DAP readings. The procedure with the highest fluoroscopy time and DAP reading was renal artery embolization, even though it was the least frequently performed procedure. IVC filter placement was found to be the procedure with the lowest fluoroscopy time and DAP reading. The table also showed that the interventional procedures have longer fluoroscopy times compared to diagnostic.

Table 2 showed the descriptive analysis of the frame exposure parameters and frame dose in mGy. The renal artery embolization has the highest frame dose. Meanwhile, the IVC filter placement has the least frame dose.

Table 3 showed a comparison of the distribution of fluoroscopy time and DAP readings for the interventional procedures considered in this study with values obtained in the literature. A difference of more than 100% was observed between the radiation dose values obtained in this study and values reported in the literature.

**DISCUSSION**:

The findings of the present study showed intra-examination variation in terms of measured DAP radiation dose, which compares with the findings of Korir et al[8]. These variations are linked to the individual peculiarities of the cases, determined by the individual anatomy and pathology severity, the patient body size, clinical technique, available accessories, protocol, and operator experience [8]. These factors also explained the larger "mean" value of DAP dose recorded when compared to the short DAP and fluoroscopy time published in the literature as shown in table 3. One of the reasons may be because the angiography center is newly established (became operational in the year 2011), and many accessories/consumables needed for speedy procedures are lacking to perform the examinations within a limited time frame. This should be of concern to the appropriate authorities in AKTH, because ofthe need to have rigorous training for the personnel and making the necessary resources available; so that procedures can be done within minimum time frame. The operator competency qualification level on the use of equipment, system dose reduction methods, and customized optimal imaging techniques were found to be essential in the optimization process [10]. Judicious choice of field of view size, and fluoroscopy pulse modes without adversely affecting the clinical quality of information obtained also play a role as a practical optimization method worthy of consideration [11].

Imaging technique and patient radiation doses:

As expected, direct linkage between DAP readings and fluoroscopy time was noted in the present study Table 1 & 2. However, no association between the kV and radiation dose values observed. This perhaps could be explained as the kV build in the protocol is constant, and only the fluoroscopy time and mA changed. An integrated dosimetry system in fluoroscopy equipment provides a practical opportunity for radiological protection of patients, and also the possibility of advising patients on potential radiation induced injuries and managing radiation dose during difficult as well as extensive procedures [7]. The machine used in the present study, has integrated DAP meter that estimates the radiation output during interventional procedures. The radiation doses measured in this study were above 2Gy, this indicates the possibility of early transient erythema in Peak Skin Dose (PSD) measurements. The skin injuries were possible in these examinations although variable individual radio sensitivity can influence the outcome. Patients exposed to radiation doses of these magnitudes should be advised on possible erythema effect. Patients with multiple interventional sessions should be checked subsequently for possible skin injuries on most exposed area of the body, and the irradiation exposure records should be analysed. The measured radiation exposure should therefore form an integral part of the patient's medical records within an institutional radiation safety program. The recording of the displayed dose data is critical towards developing age and size specific protocols, developing diagnostic reference levels, tracking radiation exposure of patients undergoing multiple sessions of fluoroscopically guided procedures or multiple imaging modalities [8]. DAP measurements can also be useful for dose estimation, and for patients found later to have been pregnant during the exposure period [8]. The time for interventional procedures was relatively long and varied even for the same type of examination. The DAP and fluoroscopy time measured in this study were above the available reference levels in the literature Table 3. The renal artery embolization was performed with longer fluoroscopy time (49.5 mins) resulting in the observed high radiation dose measurements. Conversely, IVC filter placement and lower limb arteriogram examinations were performed with less fluoroscopy time (4.0 mins) leading to lower patient radiation dose. Patient dose management in interventional angiography is complicated by numerous beam projections, diverse patient anatomy, varying lesions, and disease presentations. To promote a radiation safety culture and optimization of interventional procedures, there is a need to provide specific training on radiation protection to the interventionists, establish an effective quality assurance program, and develop guidelines for validating and verifying the operator actions [12].

The findings of this study indicate that the published optimized patient radiation dose results from Healthcare Level I (HCL I) institutions (with at least one physician for every 1000 people) are important but should not lead to the false impression that the application of radiation protection principles, X-ray equipment, and procedures, follows a standardized scheme across the world [4]. Throughout the world, radiation protection of both patients and operators is a work in progress requiring regular analysis and continuous improvement by the medical personnel, especially the imaging scientists who are more than the medical physicists in the developing countries. The difficulty of comparing radiation exposure results in the literature has been linked to a lack of standardization of data acquisition and uncontrolled variation in patient size, equipment differences, radiographic technique, and advances in technology [8].

There is an expanding use of high radiation dose modalities to perform complex medical procedures which results in high radiation exposures to patient. All the interventional procedures performed in this study, their measured DAP readings were within the levels of causing early transient erythema and skin epilation. This occurrence poses new challenges to the radiation protection community already faced with low availability of technically skilled personnel such as the radiographers, radiologists and medical physicists to handle the optimization of radiological protection of patients undergoing complex fluoroscopically guided procedures.

Based on the findings of this study professional guidelines and operational dose saving technology need to be developed and applied. The techniques for radiation dose reduction options include, the use of appropriate filtration, application of pulse fluoroscopy, appropriate compensation for various attenuation properties for patient body habitus, careful use of beam angles, reduction of the source to image distance, avoiding repeated procedures on the same patient, regular clinical training of the operators and motivation of catheterization personnel [13].

**CONCLUSION**:

Interventional procedures performed in this study demonstrated a wide variation in DAP readings for the same examination type, and the mean DAP values exceeded the available DRLs in the literature. Optimization of these high radiation dose procedures could be enhanced through clinical training on acceptable equipment performance, standard operating procedures, and development of curriculum for continuous training of operators. These training skills should minimize the fluoroscopy time, dose rate, and the number of images acquired without compromising on the quality of the clinical images that are obtained.

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