Oncology
and Radiotherapy©
19 (01) 2025 : 001-004 • RESEARCH ARTICLE

Local diagnostic reference levels for lower limb angiography procedure in Morocco

Mina Azeddou[1]*, Maroine Tahiri[2], Mounir Mkimel[2], Najat Cherif Idrissi Elganouni[1]

[1]Department of Radiology, Morpho Sciences Research Laboratory, Faculty of Medicine and Pharmacy, Cadi Ayyad University, Ar-Razi Hospital, Med VI University Hospital Center, Marrakech, Morocco
[2]Biophysics and Health Laboratory, Higher Institute of Health and Sciences, Hassan First University, Settat 26000, Morocco

ABSTRACT

The escalating utilization and complexity of fluoroscopically guided procedures contribute to prolonged examination durations and heightened risks of adverse radiation risk. Diagnostic Reference Levels (DRLs) are essential for optimizing radiation dose. The aim of this study is to establish local DRLs for Lower Limb Angiography (LLA) procedure. The investigation was conducted at at the Mohammed VI University Hospital Center in Marrakech, Morocco. The dosimetric data collected were the cumulative Dose Area Product (DAP), Fluoroscopic Time (FT), and Number of Frames (NF). The quantities' distributions were analyzed statistically, and local DRLs were determined as the 75th percentile, with the medians as typical values. The proposed LDRLs were compared to international studies. A total of 100 patients were included and performed examinations using a single C-arm machine. The Typical doses in terms of Kair were 0.21Gy, 59.34 Gy.cm2 for DAP, 1.1 min for FT and 538 frames. The derived local DRLs and Typical doses in terms of DAP, Kair, and NF were largely higher than those published by the other international studies. In terms of FT, the local DRL and typical value were significantly lower than values defined in other studies. These comparisons revealed a significant potential for optimization. This research establishes a standard for radiation dose in LLA examination at the studied hospital. These findings can inform future investigations in the country, facilitating comparative analyses.

Keywords: Diagnostic reference level; Angiography; Lower limb, Radiation dose

Address for correspondence:

Mina Azeddou

Department of Radiology, Morpho Sciences Research Laboratory, Faculty of Medicine and Pharmacy, Cadi Ayyad University, Ar-Razi Hospital, Med VI University Hospital Center, Marrakech, Morocco

E-mail: mina.azeddou@gmail.com

Word count: 1718 **Tables:** 03 **Figures:** 00 **References:** 29

Received: 16 March, 2025, Manuscript No. OAR-25-162541

Editor assigned: 18 March, 2025, Pre QC No. OAR-25-162541 (PQ)

Reviewed: 01 April, 2025, QC No. OAR-25-162541

Revised: 07 April, 2025, Manuscript No. OAR-25-162541 (R)

Published: 30 April, 2025

INTRODUCTION

Lower Limb Angiography (LLA) is a critical diagnostic tool for evaluating the vascular structures in the legs and feet. By providing detailed imaging of arteries and veins, this procedure is essential for diagnosing conditions such as atherosclerosis and stenosis. Additionally, LLA plays a crucial role in guiding therapeutic interventions, including angioplasty and stent placement, thereby significantly improving clinical outcomes. However, these benefits come with the challenge of requiring prolonged fluoroscopy and higher radiation doses, which poses risks to both patients and healthcare providers.

The International Commission on Radiological Protection (ICRP) emphasizes the need for careful documentation and follow-up when cumulative doses approach or exceed specific thresholds [1]. The patients and the medical staff are concerned, especially when performing imaging-guided procedures like angiography. These procedures may result in increasing several risks, including erythema, dermal atrophy, and ulcerations, with the severity of these conditions increasing as the dose rises. Moreover, a significant concern is the elevated cancer risk associated with the cumulative dose of radiation over time. Additionally, medical staff members are exposed to radiation doses that may be hazardous, which may affect their health.

To mitigate these dangers, the ALARA (As Low As Reasonably Achievable) principle is promoted, aiming to minimize radiation exposure while achieving necessary medical outcomes. Optimization is the fundamental radiation protection principle that applies to medical exposure, and Diagnostic Reference Levels (DRLs) are one of the tools used to support the optimization process. The concept of DRLs was introduced by ICRP in 1990, and defined as "thresholds for an investigation to optimize medical exposure during diagnostic and interventional procedures" [2]. For the interventional examinations, the DRLs should be determined through dosimetric surveys, which assess parameters like dose-area product (KAP), fluoroscopy time, and the number of frames [3]. Rather than being strict limits or thresholds that define the operator's or equipment's performance, DRLs serve as guideline levels that reflect good practice [4].

Internationally, there is a notable lack of specific DRLs for lower limb angiography. While DRLs have been established for other interventional procedures [5-9], they often do not account for the unique anatomical and technical challenges associated with lower limb angiography.

In Morocco, local Diagnostic Reference Levels (DRLs) are often explored through PhD projects, yet there is still

a lack of official bodies and policies overseeing national DRLs. The existing Moroccan studies focus generally on diagnostic imaging modalities such as computed tomography, tomography [10,11], radiography [12] for adult and pediatric patients and mammography examinations [13]. For interventional procedures, a single study was conducted by Ou-saada, et al. [7]. which proposed local DRLs in three Moroccan centers for Coronary angiography and Percutaneous transluminal coronary angioplasty [7]. However, it did not examine the DRLs specifically for LLA. Currently, neither local nor national DRLs are established in Morocco for LLA examinations. This gap is particularly concerning as the increasing use of these procedures could lead to higher radiation doses. Therefore, this study aims to establish local DRLs for lower limb angiography at the Mohammed VI University Hospital Center in Marrakech, Morocco.

MATERIALS AND METHODS

DRLs for interventional procedures

The angiography system used was a Siemens Artis Zee, equipped with a flat panel detector. Following ICRP recommendations, we manually extracted DAP and FT from the Digital Imaging and Communications in Medicine (DICOM) header. To further ensure accuracy, the x-ray system's maintenance and calibration reports were reviewed, confirming that all quality control measures were up to date.

DRLs for interventional procedures are expressed in terms of four dosimetric metrics following the ICRP publication 135. These quantities include Dose Area Product (DAP) estimated by the integral of the air kerma free-in-air in the absence of backscatter over the area of the x-ray beam in a plane perpendicular to the beam axis, expressed in Gy.cm^2. Air Kerma at the reference point (Kair) estimated by the air kerma at a point in space located at a fixed distance from the focal spot cumulated from a whole x-ray procedure, expressed in Gy [2]. Fluoroscopy Time (FT) refers to the total time duration of a procedure. Number of frame (N) refers to the number of images or frames captured during a procedure. Evaluating Fluoroscopy Time (FT) and the Number of images (N) enhances the accuracy of patient dose estimations by allowing comparisons of practices between operators, and it can help identify the reasons when radiation optimization is not achieved [2,14].

Data analysis

Data analysis was performed using Microsoft Excel 2017. The descriptive statistics were exploited to determine the minimum, maximum, mean, median, and 3rd quartile values of dose distributions including DAP, Fluoroscopy Time (FT), Air KERMA (Kair), and the Number of Frames (NF). In the present study, the local DRLs were defined as the 3rd quartile and the typical values based on the medians of dose distributions. The derived local DRLs and typical values were compared to published DRLs in international studies.

RESULTS AND DISCUSSION

The purpose of assessing Diagnostic Reference Levels (DRLs) is to pinpoint facilities where radiation protection practices may need further review to ensure optimization. This study provides the institutional DRLs for LLA at an academic hospital in Morocco. Currently, there are no DRL studies for LLA in Morocco. Given the absence of national DRL guidelines, this study may serve as a foundational step toward establishing national DRLs, which could enhance radiation dose optimization for patients and staff. The 75th percentile of a dose metric distribution is used as national DRL and the median within an institution is used as local DRL that would not exceed national DRL.

A total of 100 procedures were recorded using a single machine at one hospital. Patient ages ranged between 20 and 80 years. The proposed local DRLs for LLA examinations are presented in the **Tab. 1.** These Local DRLs are expressed in terms of Kair (Gy), DAP (Gy.cm^2), FT (min) and NF. The same table includes the minimum, maximum, mean, median and 75th percentile of quantities distributions.

The local DRL defined as the 3rd quartile for this site were 0.47 Gy for Kair, 107.98 Gy.cm^2 for DAP, 2.73 minutes for FT, and 3.45 for NF. Since it is a single study facility, the typical value and dose were defined by

Tab. 1. The proposed local DRLs for LLA examinations in terms of Kair (Gy), DAP (Gy.cm2), FT (min) and NF.

Dosimetric parameters	Min	Max	Mean	3rd quartile	Median
Kair (Gy)	0.01	1.29	0.3	0.47	0.21
DAP (Gy.cm^2)	2.96	383.64	81.38	107.98	59.34
FT (min)	0.1	21.6	2.69	2.73	1.1
NF (frame)	158	2437	626	345	538

median values. The typical doses were 0.21 Gy, 59.34 mGy.cm^2 for Kair and DAP, and typical values were 1.1 min, 538 frames for FT and NF, respectively.

Tab. 2. shows the comparison of local DRLs for LLA presented in this study with those published in international surveys. For DAP, the comparison revealed that local DRLs established in our study are significantly higher than those reported by France [15], Belgium [16] Spain [17] and United Kingdom [18]. The exception was for the Switzerland study [19], which presented values exceed largely the derived local DRLs (210 # 107 mGy). These differences can be attributed to the procedure complexity which may vary for different clinical indications for the same procedure [2]. The X-ray equipment performance, and patient size [20]. The DAP differences, even with the same equipment, are largely influenced by operator factors. One key factor is patient size, which directly affects the exposure parameters. The critical aspect is the variability in radiologist experience, with distinctions between senior and junior practitioners impacting the outcomes, particularly in interventional settings [20,21].

For the Fluoroscopy Times (FT) recorded were ranged from 0.1 to 21.6 min, and the local DRL was significantly lower than those reported in the compared studies. This finding may be due to the Digital Subtraction Angiography

Tab. 2. Comparison of typical values with single facility published studies.

Country (Year of publication)	3rd quartile			
	DAP (Gy.cm²)	FT (min)	NF	K_{air} (Gy)
This study	107,98	2,73	345	0.47
France (Etard, et al. 2017) [15]	72	5,2	250	0.15
Belgium (Bleeser, et al. 2008) [16]	75	---	---	---
Spain (Vano, et al. 2009) [17]	73	3,3	161	---
Switzerland (Aroua, et al. 2007) [18]	210	8	150	---
United Kingdom (Aroua, 2007) [19]	56	5.9	---	---

(DSA) mode, which was deliberately linked to FT and exposure reduction [22]. Similarly to the compared studies, we observed a poor FT and strong DAP. In this context, several studies revealed that the correlation between FT and dose metrics is very poor [23,24]. The FT parameter is not a reliable measure of radiation damage and is less significant than diagnostic reference levels (DRL), making it inadequate for radiation protection purposes [23-26]. Regarding NF, the local DRLs exceeds all international DRLs, with the closest being those from France (345 *vs.* 250 frames). For Kair, the same trund was noted.

In this study conducted in a single facility, the median value will be proposed as a typical value in order to be used specially locally or to detect further optimization [2]. A comparison of these values against published median ones was outlined in **Tab. 3**. The present DAP value was notably above three of four compared studies. The lowest difference was within Tristam, et al. study (59.34 mGy.cm² *vs.* 11 mGy.cm²) [26]. Regarding FT results, the value was largely below other studies. The lowest difference was within Rana, et al. study [27] Regarding NF, or study DRL exceeds all national DRLs, with the closest being those from France (345 *vs.* 250 frames). For Kair, the same trund was noted.

These results demonstrate a significant opportunity to optimize procedures, including equipment performance (characterization), settings, and examination protocols, which should be tailored to the patient's weight as corrective actions to reduce radiation dose. A large sample was used to compare to other single facilities studies. However, a major limitation of this study was that it focused on just one procedure [28,29]. Analysis correlating dose level with procedure complexity and operator experience was not conducted, and this should be considered in future studies.

Tab. 3. Comparison of present dose data with single facility studies published DRLs.

	Median value			
	N (frames)	DAP (Gy.cm²)	FT (min)	K_{air} (Gy)
This study	100	59.34	1.1	0.21
(Rana, et al. 2018) [27]	9	10.1	4.2	---
(Erskine, et al. 2014) [28]	123	9.2	10.3	---
(Pitton, et al. 2012) [29]	60	79	---	---
(Tristram, et al. 2022) [26]	216	16	14.4	0.07

CONCLUSION

Local DRLs and typical values have been proposed specifically for Lower limb angiography in terms of DAP, Kair, NF, and FT. The derived local DRLs and typical values were higher than those of published studies. Furthermore, a significant variation in radiation doses among patients undergoing similar procedures was observed, highlighting the need to improve dose management and refine clinical practices. This study suggests that finalizing and expanding this investigation is imperative to establish national reference levels for interventional procedures in Morocco.

FUNDING

This research did not receive any specific funding.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

The research data associated with this article are included within the article.

AUTHOR CONTRIBUTION STATEMENT

Mina Azeddou, performed the research, analyzed data and wrote the paper.

Maroine Tahiri, performed the research and wrote the paper.

Mounir Mkimel, designed the study and writing-editing.

Najat Cherif Idrissi Elganouni, designed the study and writing-editing.

Mounir Benmessaoud, designed the study and writing-editing.

ETHICS APPROVAL

Institutional Review Board approval was obtained.

INFORMED CONSENT

This article does not contain any studies involving human subjects.

REFERENCES

1. Valentin J. Avoidance of radiation injuries from medical interventional procedures, ICRP Publication 85. Annals of the ICRP. 2000; 30(2):7-10.
2. Vañó E, Miller DL, Martin CJ, Rehani MM, Kang K, et al. ICRP publication 135: diagnostic reference levels in medical imaging. Annals of the ICRP. 2017; 46(1):1-44.
3. European Commission: Directorate-General for Environment. (1999). Guidance on Diagnostic Reference Levels (DRLs) for medical exposures. Publications Office.
4. ICRP. (2007). Radiation protection in medicine.
5. Guenego A, Mosimann PJ, Pereira VM, Nicholson P, Zuber K, et al. Proposed achievable levels of dose and impact of dose-reduction systems for thrombectomy in acute ischemic stroke: an international, multicentric, retrospective study in 1096 patients. Euro Radiol. 2019; 29:3506-3515.
6. Ihn YK, Kim BS, Jeong HW, Suh SH, Won YD, et al. Monitoring radiation doses during diagnostic and therapeutic neurointerventional procedures: multicenter study for establishment of reference levels. Neurointervention. 2021; 16(3):240-251.
7. Ou-Saada I, Boujemaa S, Campoleoni M, Brambilla R, Bentayeb F. Local diagnostic reference levels in interventional radiology. J Med Imaging Radiat Sci. 2020; 51(2):307-311.
8. Siiskonen T, Ciraj-Bjelac O, Dabin J, Diklic A, Domienik-Andrzejewska J, et al. Establishing the European diagnostic reference levels for interventional cardiology. Physica Medica. 2018; 54:42-48.
9. Tuthill E, O'hora L, O'donohoe M, Panci S, Gilligan P, et al. Investigation of reference levels and radiation dose associated with abdominal EVAR (endovascular aneurysm repair) procedures across several European Centres. Euro Radiol. 2017; 27:4846-4856.
10. Benmessaoud M, Housni A, Elmabrouki M, Essasnaoui F, Sadiki N, et al. Derivation of local diagnostic reference levels for common adult computed tomography examinations in Moroccan hospital. Radiat Prot Dosimetry. 2021; 194(4):208-213.
11. Benmessaoud M, Dadouch A, Maghnouj A, Lemmassi A, Tahiri M, et al. Establishment of local diagnostic reference levels for paediatric abdominal-pelvis and Chest-abdominal-pelvis computed tomography in Morocco: suggests the need for improved optimization efforts. Radiat Prot Dosimetry. 2023; 199(10):1129-1141.
12. Talbi M, Tahiri Z, Eddaoui K, El Mansouri M, Nhila O, et al. Local diagnostic reference levels (LDRLs) for routine X-ray examinations in Morocco. Radioprotection. 2022; 57(2):149-155.
13. Talbi M, Nhila O, Tahiri Z, Eddaoui K, Khalis M. local Diagnostic Reference Levels (LDRLs) for Full-Field Digital Mammography (FFDM) and Digital Breast Tomosynthesis (DBT) procedures in Morocco. J Med Imaging Radiat Sci. 2022; 53(2):242-247.
14. Fisher RF, Applegate KE, Berkowitz LK, Christianson O, Dave JK, et al. AAPM medical physics practice guideline 12. a: fluoroscopy dose management. J Appl Clin Med Phys. 2022; 23(3):e13526.
15. Etard C, Bigand E, Salvat C, Vidal V, Beregi JP, et al. Patient dose in interventional radiology: a multicentre study of the most frequent procedures in France. Euro Radiol. 2017; 27:4281-4290.
16. Bleeser F, Hoornaert MT, Smans K, Struelens L, Buls N, et al. Diagnostic reference levels in angiography and interventional radiology: a Belgian multi-centre study. Radiat Prot Dosimetry. 2008; 129(1-3):50-55.
17. Vano E, Sanchez R, Fernandez JM, Gallego JJ, Verdu JF, et al. Patient dose reference levels for interventional radiology: a national approach. CardioVasc Interv Radiol. 2009; 32:19-24.
18. https://www.gov.uk/government/publications/diagnostic-radiology-national-diagnostic-reference-levels-ndrls/ndrl#national-drls-for-computed-tomo
19. Aroua A, Rickli H, Stauffer JC, Schnyder P, Trueb PR, et al. How to set up and apply reference levels in fluoroscopy at a national level. *Eur Radiol*. 2007; 17:1621-1633.
20. Crowhurst JA, Whitby M, Savage M, Murdoch D, Robinson B, et al. Factors contributing to radiation dose for patients and operators during diagnostic cardiac angiography. J Med Radiat Sci. 2019; 66(1):20-29.
21. Mesbahi A, Aslanabadi N, Mehnati P. A study on the impact of operator experience on the patient radiation exposure in coronary angiography examinations. Radiat Prot Dosimetry. 2008; 132(3):319-323.
22. Gyánó M, Berczeli M, Csobay-Novák C, Szöllősi D, Óriás VI, et al. Digital variance angiography allows about 70% decrease of DSA-related radiation exposure in lower limb X-ray angiography. Sci Rep. 2021; 11(1):21790.
23. Balter S, Miller DL, Vano E, Ortiz Lopez P, Bernardi G, et al. A pilot study exploring the possibility of establishing guidance levels in x□ ray directed interventional procedures. Med Phys. 2008; 35(2):673-680.
24. Heilmaier C, Zuber N, Berthold C, Kara L, Weishaupt D. Establishing local diagnostic reference levels in IR procedures with dose management software. J Vasc Interv Radiol. 2017; 28(3):429-441.
25. Miller DL, Balter S, Schueler BA, Wagner LK, Strauss KJ, et al. Clinical radiation management for fluoroscopically guided interventional procedures. Radiology. 2010; 257(2):321-332.
26. Tristram J, Steuwe A, Kröpil F, Thomas C, Rubbert C, et al. Typical doses and typical values for fluoroscopic diagnostic and interventional procedures. J Radiol Protection. 2022; 42(2):021510.
27. Rana BS, Kumar S, Ahuja CK, Singh NP, Yadav MK, et al. Estimation of radiation exposure to the patients in diagnostic and therapeutic interventional procedures. Radiat Prot Dosimetry. 2018; 181(3):290-300.
28. Erskine BJ, Brady Z, Marshall EM. Local diagnostic reference levels for angiographic and fluoroscopic procedures: Australian practice. Australas Phys Eng Sci Med. 2014; 37:75-82.
29. Pitton MB, Kloeckner R, Schneider J, Ruckes C, Bersch A, et al. Radiation exposure in vascular angiographic procedures. J Vasc Interv Radiol. 2012; 23(11):1487-1495.