Acta Cardiol Sin 2019;35:27–31
Original Article
doi: 10.6515/ACS.201901_35(1).20180730A

Peripheral Arterial Occlusive Disease

Evaluation of Radiation Exposure on Physicians During Angioplasty for Hemodialysis Access Dysfunction

Po-Sen Huang,[1] Zhih-Cherng Chen,[1,2] Kuo-Ting Tang[1] and Wei-Ting Chang[1,3]

Background: Percutaneous interventions help patients with various cardiovascular diseases, however radiation exposure is a safety concern for both patients and health care providers. We previously reported that dose area product (DAP) is apparently different in central body and upper-limb areas during percutaneous transluminal angioplasty for arteriovenous shunt dysfunction. In this study, we investigated the precise radiation dose at the patients' back and at the non-targeted organs of the operators.

Methods: The radiation dose was measured with optically stimulated luminescent dosimeters and DAP on several sites including the backs of the patients, gonads, hands and lens of the operators. The studied populations were categorized into central, upper arm and forearm groups based on the lesion sites.

Results: The results indicated that there was a significantly higher radiation dose in the central lesion group than in the upper arm and forearm groups. Conversely, there were no specific differences in total procedure time and fluoroscopy time among groups. The radiation exposure doses in the operators showed that regardless of the site, including lens, hands and gonads of the operators, the radiation dose was significantly higher in the central lesion group.

Conclusions: The closer the lesion site to the body center, the higher the radiation exposure in both the patients and operators.

Key Words: Arteriovenous shunt dysfunction • Central lesion • PTA • Radiation exposure

INTRODUCTION

In the first quarter of 2017, more than 78,000 people received hemodialysis 78,000 people in Taiwan, and the prevalence rate is the highest in the world (incidence of 458 per million population; prevalence of 3,138 per million population).[1] Arteriovenous fistula (AVF) or arteriovenous graft (AVG) dysfunction is mainly caused by vascular stenosis, leading to inadequate dialysis and eventually thrombosis. Percutaneous transluminal angioplasty (PTA) has become the first-line modality for treating stenosis-related access dysfunction.[2] The necessity of PTA has recently increased due to the increasing hemodialysis population and also the issue of the dialysis access narrowing after repeated usage and restenosis after previous PTA.[3,4] Radiation exposure for cardiologists, especially those performing hemodialysis interventional therapy, is higher than that in those performing coronary angiography when the operators are closer to the main radiation beam.[5,6] The long-term impact of radiation exposure is associated with an increased risk of cancer.[7] Based historically on survivors of atomic bombs and nuclear accidents, leukemia, thyroid cancer,

Received: April 10, 2018 Accepted: July 30, 2018
[1]Division of Cardiology, Department of Internal Medicine, Chi-Mei Medical Center; [2]Department of Pharmacy, Chia Nan University of Pharmacy and Science; [3]Department of Biotechnology, Southern Taiwan University of Science and Technology, Tainan, Taiwan.
Corresponding author: Dr. Wei-Ting Chang, Division of Cardiology, Department of Internal Medicine, Chi-Mei Medical Center, No. 901, Zhong Hua Road, Yong Kang Dist., Tainan 710, Taiwan. Tel: 886-6-281-2811; Fax: 886-6-281-2811; E-mail: weiting990101@gmail.com

and breast cancer are the most common types of cancer associated with radiation exposure.[7] It has also been reported that 0.6-1.8% of cancers may be caused by diagnostic X-rays.[8] Currently, the radiation dose delivered during each single procedure of cardiac catheter intervention is typically low, and the net benefits for current heart disease outweigh the possible risks of future malignancy. Repeated radiation exposure increases the lifelong cumulative dose of radiation, which increases the hazard to both patients and operators. For example, an increasing number of cases have emerged with cardiac fluoroscopy-induced radiation skin ulcers, and higher doses of radiation (> 15 Gy) may contribute to the more severe forms of skin damage.[9] Despite emerging evidence of the safety concerns of radiation exposure, a definite safety threshold of radiation dose is still lacking, especially for interventions at different regions of the body.[10,11] Therefore, the purpose of our study was to evaluate the radiation exposure of both patients and operators during percutaneous interventional procedures for different lesion sites of AVF.

MATERIALS AND METHODS

This study was approved by the Chi-Mei Medical Center Institutional Ethics Committee (10501-003), and the requirement for informed patient consent was waived. Using a stationary floor-mounted under-couch C-arm system (Siemens Artis zee, Washington, DC), continuous fluoroscopy and digital subtraction angiography (DSA) were performed at 3 frames per second. During fluoroscopy, a 0.3-mm copper filter was applied. The field of view, which varies during the procedure, was widely open without Collimation Shelter. Dose-area product (DAP) was measured with a flat ionization chamber (Diamentor K1S; PTW, Freiburg, Germany) built into the angiography system. Reference point air kerma, a measure of energy transferred from radiation to matter, was displayed as skin dose in milligrays on the flat-panel system. Before the PTA procedure was initiated, three optically stimulated luminescent dosimeters were positioned on the operator, including one pasted inside the glove, the second attached to the left side of their eye goggles, and the third placed on the procedure gown inside the skirt to measure gonad exposure. One dosimeter was positioned on the patients' back and the radiation exposure was compared to that recorded by the machine. Each dosimeter was individually calibrated before the PTA procedure. After the PTA procedure, the dosimeters were immediately collected and the data were analyzed in the lab. The recorded parameters included X-ray tube voltage (kV), tube current (mA), absorbed dose (mGy), DAP mGy.cm^2), and equivalent dose (mSv). The flat panel was placed over the site for the investigation during the hemodialysis access angiography and intervention procedures. We categorized the lesion sites of the intervention into three groups, including the central (subclavian vein to superior vena cava), upper arm (basilic, cephalic vein of the upper arm to axillary vein and brachial artery) and forearm (basilica, cephalic vein of the forearm and radial artery) groups. Equivalent doses and DAPs at each site were the primary outcome. The procedure was performed with an 18-gauge needle or an introducer sheath for angiography of the entire efferent vein and of the arteriovenous anastomosis to visualize the AVF or AVG map. The stenosis was then treated with balloon angioplasty until a residual stenosis less than 30% had been achieved. For each procedure, DAP, fluoroscopy time, total procedure time, and the total number of DSA series were recorded. Reference point air kerma was measured for all procedures.

Comparisons of continuous variables were performed using the Student's t-test and ANOVA. A two-tailed p-value < 0.05 was considered to be significant for statistical analysis in this study. All analyses were performed using SAS software (SAS, version 9.2; SAS, Cary, NC).

RESULTS

A total of 198 male and 125 female patients were included. The mean age was 64 $\pm$ 6.15 years (range, 26-87 years). PTA was performed in cases with stenosis or thrombosis of the vein or graft (Figure 1). There were no significant differences in baseline characteristics between groups, and the prevalence of previous PTA was similar (Table 1). The absorbed dose in the patients (Figure 2A) during interventions for different lesion sties significantly decrease from the central 853 $\pm$ 54 mGy, upper arm 394 $\pm$ 15 mGy, to forearm 30.78 $\pm$ 1.6 mGy ($p < 0.001$) groups. Similarly, DAP which is usually used to in-

dicate the radiation dose in patients, was significantly increased in the central lesion group (central 1775 ± 90 mGy.cm^2 compared with the upper arm group 574 ± 16 mGy.cm^2 and forearm group 141 ± 5 mGy.cm^2; p < 0.001) (Figure 2B). Conversely, there were no specific correlations between the (Figure 3A) total procedure time, fluoroscopy time (Figure 3B) and radiation doses measured at different points due to the different need for DSA in each patient.

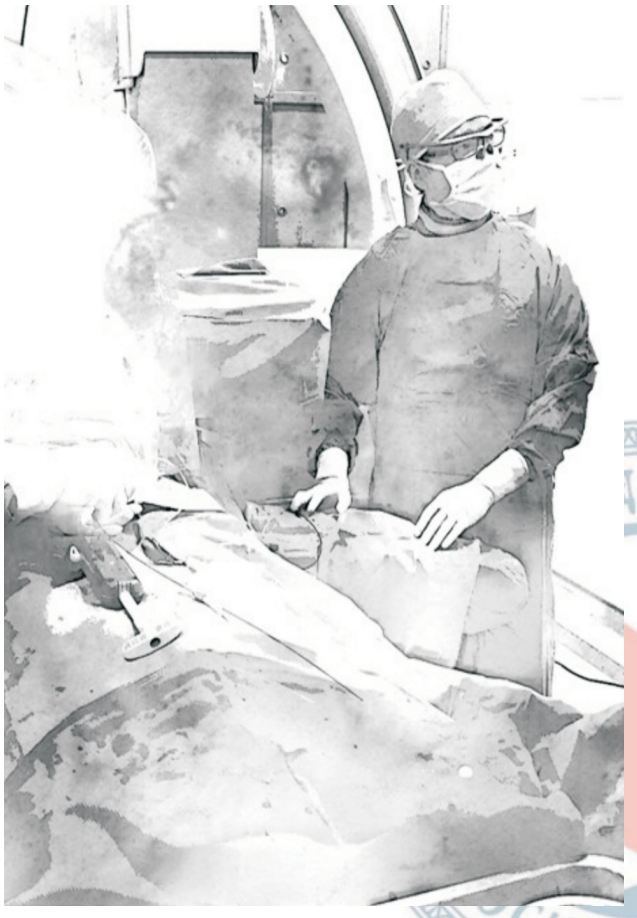

Figure 1. *The operator processing left upper arm percutaneous transluminal angioplasty on the left side of the patient.*

Table 1. Baseline characteristics of patients receiving intervention for the central, upper arm and forearm lesions

	Central	Upper arm	Forearm
Total number (n = 323)	(n = 87)	(n = 125)	(n = 111)
Age, yrs	61 ± 14	53 ± 12	65 ± 10
Weight, kg	72 ± 3	68 ± 2	63 ± 2
Male sex, %	60 (69)	32 (26)	35 (32)
Diabetes mellitus	31 (36)	37 (30)	25 (24)
Hypertension	61 (70)	86 (69)	75 (68)
Hypercholesterolemia	58 (67)	85 (68)	71 (64)
Prior PTA	22 (25)	38 (30)	30 (27)

Values are mean ± SD or n (%).
PTA, percutaneous transluminal angioplasty.

Regarding the operators, the radiation dose to the lens (Figure 4A) was significantly higher in the central site group (127 ± 4 μSv) than those to the upper arm group and forearm group (60 ± 1 and 30 ± 1 μSv, respectively) (p < 0.001). Likewise, the radiation doses measured at the level of the hands in the central group were significantly elevated compared with those of the upper arm and the forearm groups (124 ± 3; 50 ± 1; 25 ± 1 μSv, respectively; p < 0.001) (Figure 4B). Also, for the central site group, the radiation dose to the gonads (Figure 4C) (118 ± 3 μSv) was significantly higher than the radiation dose to the upper arm (50 ± 1 μSv), and forearm (20 ± 1 μSv) (p < 0.001).

Fluoroscopy time, which had an increased correlation with total procedure time (not shown), in the central and upper arm groups was significantly longer compared with the forearm group, while the recanalization procedures was usually longer for the lesions in the central and upper arm regions.

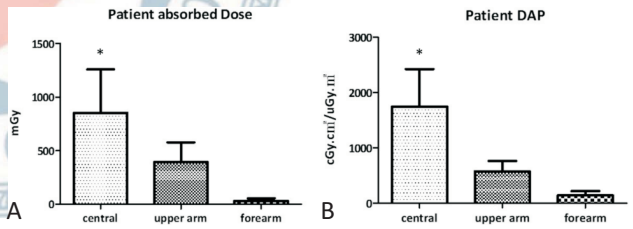

Figure 2. *(A) The absorbed dose of dosimeter on patients' back significantly increased in the group of central lesion. (B) Dose area product (DAP) measured in the X-ray machine was also significantly high in the central group.*

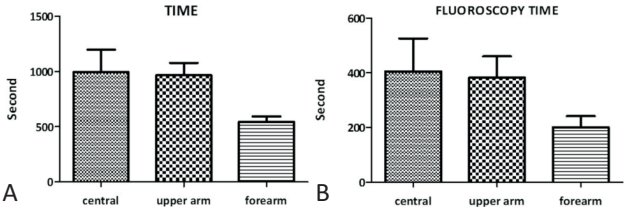

Figure 3. *There was a slight declines of both (A) total procedure time and (B) fluoroscopy time in the forearm group but no statistically significant.*

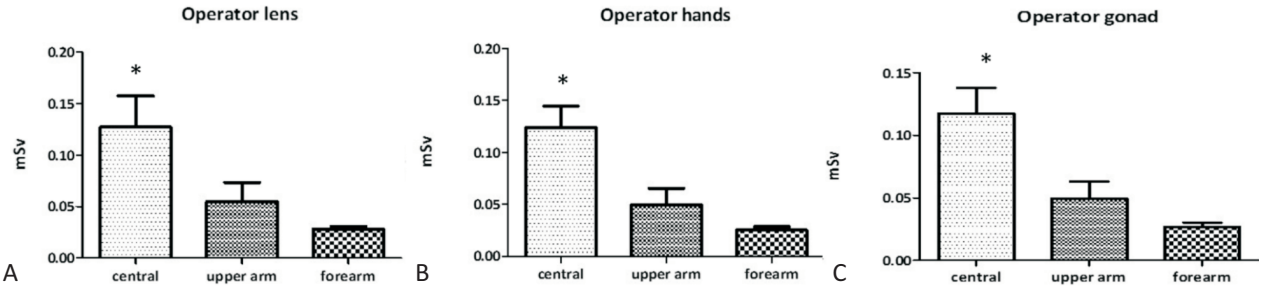

Figure 4. *(A) The radiation doses to the operators' lens, (B) hands and (C) gonad were all significantly elevated in the central lesion group (* p < 0.001).*

DISCUSSION

According to the review article by Lin in 2010, a radiation dose above 100 mSv is significantly associated with an increased risk of cancer. Although the cancer risk at doses between 10 to 100 mSv is controversial, the linear no-threshold theory is widely used for assessing the potential risks of low-dose radiation.[12,13] This raises the issue of concerns of radiation hazard not only in the patients but also in the operators. Compared with the results of a previous meta-analysis, the radiation exposure in the operators of coronary interventions (mean value 107 μSv for percutaneous coronary intervention via transradial access under basic radiation protection) was lower than that in PTA for arteriovenous shunt (mean value at the operator's gonad 61 μSv, which is the site closest to the body center) in this study.[14] This demonstrates that the radiation dose is lower during PTA than coronary interventions. However, the importance of protection from radiation exposure in PTA interventions should not be ignored.

A similar study published by Stavas et al. indicated that the radiation dose to the operator's hand was associated with fluoroscopy time but independently of graft-related factors.[15] Conversely, our results revealed that the dose was mainly correlated with the lesion site but less with the total procedure time. It is known that owing to the complexity of central lesions, the intervention may require a longer fluoroscopy time for device delivery and more cineradiography time when awaiting contrast flow enhancement. Another important factor influencing the radiation dose in central lesions is the automatic adjustment of radiation production power by the machine to achieve the required image quality. This can contribute to more radiation emission, while higher penetration power is required for thicker tissue influoroscopy. Furthermore, the radiation dose can be reduced in upper arm and forearm lesions by actively reducing the field of view to achieve X-ray beam collimation, which also reduces the radiation production power.

Because the deployed range of ceiling-mounted lead screening is designed for coronary interventions, it is mainly located over the right side of the patient. However, the operators in our lab mostly stand on the left side of the patient while performing PTA for AV shunt dysfunction. In addition, the space on the left side is narrow for a mobile lead barrier in our lab. Therefore, the use of a lead screen or barrier is relatively rare. Moreover, for convenience during the procedure, some operators do not wear full protection, and the lead screen was often moved away. This can cause lens opacities or cataracts after several years of work.[16] Correspondingly, our results showed that the radiation dose at the operators' lens was similar to that at the hands. Recently, Roguin et al. reported several interventional physicians with the head and neck tumors. This raises concerns of brain cancer due to disproportionate reports of left-sided tumors suggesting the possibility of a causal relation to occupational radiation exposure.[17]

Of the three principles of radiation protection, shielding may be easiest than time and distance for PTA procedures. According to the study by Ting et al. in 2017, scatter radiation could be reduced considerably over the hands, lens, and gonads of the operator and also over the patient's abdomen, chest, lens and thyroid using a shielding drape, RADPAD, a lead-free surgical drape containing Bi and Ba with a dimension of 11-in × 34-in and weighing < 150 g (Worldwide Innovations & Technologies, Kansas City, US).[18] In their study, it was accidentally found that the shielding drape reminded the operators

not to put their hand under the main radiation beam.

Our study has several limitations. First, our data did not record the field-of-view, which affects air kerma. In the PTA procedure, to reduce the radiation dose, the field-of-view was usually set as small as possible. Second, the usage time of ceiling-mounted lead screens and mobile lead barriers was not measured. Some operators removed the radiation shielding because that often interfered with vision during the manipulation of PTA devices. Third, we did not differentiate the types (AVF or AVG) or sides (left or right) of AV shunt. Fourth, the procedures were not standardized, including the position of the operator, the angle of the radiation beam and the puncture site.

CONCLUSIONS

In conclusion, the closer the lesion site toward the body center, the higher the radiation exposure of the operators and patients. Although the radiation exposure was relatively lower in PTA compared with coronary interventions, the radiation hazard should still be kept in mind because a higher number of PTA procedures increases the chance of the operator being directly exposed to radiation beams. Therefore, the use of radiation shielding is necessary, and further work on the modification of shielding devices for better protection and application (avoiding interfering with the operation) is urgently needed.

CONFLICT OF INTEREST

None.

REFERENCES

1. Prasad N, Jha V. Hemodialysis in Asia. *Kidney Dis* 2015;1:165-77.
2. Ko RC, Liao MT, Lin L, et al. Feasibility and safety of coronary procedures via an arteriovenous graft approach in patients on maintenance hemodialysis. *Acta Cardiol Sin* 2015;31:550-6.
3. Chen TY, Lin L, Hsieh MY, et al. Deficiency of endothelial progenitor cells associates with graft thrombosis in patients undergoing endovascular therapy of dysfunctional dialysis grafts. *Acta Cardiol Sin* 2017;33:81-91.
4. Sugarman JR, Frederick PR, Frankenfield DL, et al. Developing clinical performance measures based on the Dialysis Outcomes Quality Initiative Clinical Practice Guidelines: process, outcomes, and implications. *Am J Kidney Dis* 2003;42:806-12.
5. Niklason LT, Marx MV, Chan HP. Interventional radiologists: occupational radiation doses and risks. *Radiology* 1993;187:729-33.
6. Schueler BA, Vrieze TJ, Bjarnason H, Stanson AW. An investigation of operator exposure in interventional radiology. *Radiographics* 2006;26:1533-41.
7. Thompson DE, Mabuchi K, Ron E, et al. Cancer incidence in atomic bomb survivors. Part II: solid tumors, 1958-1987. *Radiat Res* 1994;137:S17-67.
8. Berrington de Gonzalez A, Darby S. Risk of cancer from diagnostic X-rays: estimates for the UK and 14 other countries. *Lancet* 2004;363:345-51.
9. Balter S, Miller DL. Patient skin reactions from interventional fluoroscopy procedures. *Am J Roentgenol* 2014;202:W335-42.
10. Godino C, Maccagni D, Pavon AG, et al. Estimating incidence of organ cancer related to PCI radiation exposure in patients treated for acute and chronic total occlusions. *J Invasive Cardiol* 2013;25:441-5.
11. Picano E, Vano E. The radiation issue in cardiology: the time for action is now. *Cardiovasc Ultrasound* 2011;9:35.
12. Lin, Eugene C. Radiation risk from medical imaging. *Mayo Clin Proc* 2010;85;1142-6.
13. Vano E, Sanchez R, Fernandez JM, et al. Patient dose reference levels for interventional radiology: a national approach. *Cardiovasc Intervent Radiol* 2009;32:19-24.
14. Plourde G, Pancholy SB, et al. Radiation exposure in relation to the arterial access site used for diagnostic coronary angiography and percutaneous coronary intervention: a systematic review and meta-analysis. *Lancet* 2015;386:2192-203.
15. Stavas JM, Smith TP, DeLong DM, et al. Radiation hand exposure during restoration of flow to the thrombosed dialysis access graft. *J Vasc Interv Radiol* 2006;17:1611-7.
16. Vano E, Gonzalez L, Fernández JM, Haskal ZJ. Eye lens exposure to radiation in interventional suites: caution is warranted. *Radiology* 2008;248:945-53.
17. Roguin A, Goldstein J, Bar O, Goldstein JA. Brain and neck tumors among physicians performing interventional procedures. *Am J Cardiol* 2013;111:1368-72.
18. Ting CY, Wu WS, Tang KT, et al. Evaluation of radiation dose during the percutaneous angioplasty for arteriovenous shunt assembling. *Radiat Phys Chem* 2017:140:213-6.