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INTERVENTIONAL RADIOLOGY

ORIGINAL ARTICLE

Operator radiation dose during trans-hepatic arterial chemoembolization: different patients' positions via transradial or transfemoral access

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PURPOSE

This study aimed to compare the radiation dose received by the operator among different patients' positions via transradial access (TRA) or transfemoral access (TFA) during transarterial chemoembolization (TACE) for hepatocellular carcinoma (HCC).

METHODS

A total of 120 patients with HCC undergoing TACE for the first time between January and November 2019 were randomized into 4 groups with 30 patients in each group. In group A, patients were placed in the foot-first position with the left upper arm abducted, and TACE was performed via the left radial artery. In group B, patients were placed in the conventional head-first position with the left hand placed at the left groin, and TACE was performed via the left radial artery. In group C, patients were placed in the conventional head-first position, and TACE was performed via the right radial artery. In group D, patients were placed in the conventional head-first position, and TACE was performed via the right femoral artery. Before each procedure, thermoluminescent dosimeters were taped at 7 different body parts of the operator and the radiation dose was measured and collected after the procedure. The normalized radiation dose was also calculated. Procedural parameters included radiation dose, fluoroscopy time (FT), dose–area product (DAP), and air kerma (AK) were recorded. Patients' demographics, tumor baseline characteristics, radiation dose, and procedural parameters were compared between groups.

RESULTS

No significant differences were found in patients' demographics, tumor baseline characteristics, as well as in total FT, DAP, and AK. However, significant differences were found in the total radiation dose received by the operator and the doses on the pelvic cavity and the right wrist ($P < .05$). In group C, the radiation doses received on the pelvic cavity, the right wrist, and the total radiation doses were relatively higher. Significant differences were also found in the normalized radiation doses received by the operator on the thyroid, chest, left wrist, right wrist, and pelvic cavity, and the total normalized doses (all $P < .05$). Similarly, the radiation doses received by the operator at the aforementioned parts in group C were higher, while those in group A were lower.

CONCLUSION

No statistically significant differences were observed in the FT, DAP, and AK in TACE via TRA when patients were placed in different positions. However, TACE via the left TRA, with patients in the feet-first position, reduced the radiation dose received by the operator, thereby reducing the radiation risk.

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Liver cancer remains a global health challenge and its incidence is growing worldwide. Hepatocellular carcinoma (HCC) is the most common form of liver cancer and accounts for ~90% of cases.[1] Transarterial chemoembolization (TACE) is one of the most commonly used non-surgical therapeutic methods for HCC.[2] Since Shiozawa et al.[3] first reported the performance of transradial access (TRA) on patients with HCC undergoing TACE, this access has been increasingly used in the peripheral vascular intervention,[4-7] with higher patient acceptance and fewer complications.[3] A study of more than 1500 cases of non-coronary interventional therapy via TRA, including 485 patients who underwent TACE, verified the feasibility and safety of this access, with the success rate of 98.2% and the overall complication rate was less than 3%.[5]

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Interventional therapy brings immense benefits to patients. However, it is associated with radiation-induced damage.[8] For patients, radiation from one or several interventional procedures generally does not cause any harm. Nevertheless, for operators performing interventional therapy, long-term fluoroscopy may cause the cumulative dose to exceed the threshold of the deterministic effect, thus bringing irreversible damage to their bodies.[9] In recent years, the deterministic and the stochastic effects of ionizing radiation to the interventionalists have received more and more attention.[10,11] Previous studies on non-coronary intervention showed that the radiation dose received by patients undergoing TACE via TRA was similar to that of via transfemoral access (TFA), but the radiation dose received by the operator was significantly higher via TRA.[12] However, no in-depth study was conducted on the radiation dose received by the operator. For example, Yamada et al.[13] concluded that the radiation dose received by the operator during TACE via TRA was lower than that of via TFA. However, the conclusion was limited by the small sample size, and only the radiation dose on the waist was measured. In addition, only 1 patient's position of TRA was included in that study, but different patients' positions were used in different centers, and the choice of the left and right TRA also makes a difference.[4,14-17] To our knowledge, no study showed which position brought lower radiation dose to the operator. This study aimed to compare the radiation doses received by the operator during TACE via TRA with 3 common patient positions and TFA.

Main points

- A growing number of transarterial chemoembolization (TACE) procedures via transradial access (TRA) were performed because of higher patient satisfaction, lower radiation exposure, and lower complication rate.
- Radiation doses received by the operator were still unclear when patients were placed in different positions.
- No statistically significant differences were observed in the fluoroscopy time, dose–area product, and air kerma in TACE via TRA when patients were placed in different positions in our study.
- TACE via the left TRA, with patients placed in the abduction position, might effectively reduce the radiation dose received by the operator and the radiation risk.

Methods

This was a randomized controlled study, which included 120 patients who were undergoing TACE for the first time in our hospital from January to November 2019. Patients were randomly divided into 4 groups (A, B, C, and D) using random software according to different patients' positions and accesses, with 30 patients in each group. In group A, patient was placed opposite to the conventional TFA position (foot-first), and the left upper arm was abducted on the hand placement plate at 70°-90°. The operator stood on the left side of the patient and punctured the left radial artery, as shown in Figure 1a. In group B, patient's position was the same as that of the conventional TFA (head first), and the left palm was placed upward on the left groin. The operator stood on the right side of the patient and punctured the left radial artery, as shown in Figure 1b. In group C, patient's position was the same as that of conventional TFA (head first), and the operator stood on the right side of the patient and punctured the right radial artery, as shown in Figure 1c. In group D, patient was placed in the conventional TFA position, and the operator punctured the right femoral artery, as shown in Figure 1d. The patients aged > 18 years, with a performance status of 0- or 1-point, with an obvious radial artery pulse, and with a clinical diagnosis of HCC were included in the study. The patients whose radial artery pulse was disappearing or weakening, who had a history of cerebral apoplexy, who had severe calcification of the aortic arch, or who needed dialysis were excluded.

All patients signed informed consent forms before the procedures. Thermoluminescent dosimeters (TLDs) were put into numbered small plastic bags before the procedures and stuck on different parts of the operator outside the lead apron, including the head (next to the left orbit), thyroid position on the neck, left fore-breast, pelvic cavity, left wrist, right wrist, and feet. TLDs were retrieved after the procedures, then sent to detect the dose, and record the readout value using RGD-3B TLD.

The procedures were performed by the same physician with 1.7 m height and 9-year experience in interventional radiology, who was well trained in each technique, and used the same digital subtraction angiography (DSA) machine (Philips Allura Xper FD 20) to avoid the differences in the operational process and the height of the operator. The height of the operating table, angle of the tube, image magnification, and dose mode adopted by the 4 groups were set similarly. The conventional movable glass baffle and lead baffle under the bed were used for radiation shielding. The movable glass baffle was set as far away from the radiation source and close to the operator as possible, while the lead baffle under the bed was set as close to the bed as possible to achieve the best shielding effect.

TACE procedures

TRA (groups A, B, and C): Allen's test was performed before the procedure to check the blood flow of the radial artery and the ulnar artery. The left or right hand and the forearm skin were routinely disinfected, with a bandage roll put under the wrist to make it easy to expose the skin on the radial artery. The sterile towel was spread, and the point 1-2 cm above the rasceta with the strongest radial artery pulse was selected as the puncture point. A small amount of mixed solution (5 mL of 2% lidocaine + 5 mL of 500 μg nitroglycerin) was used for local anesthesia, and the radial artery was accessed with a 5 F radio-specific sheath set (Terumo) using the Seldinger technique. Heparin 3000 IU and 5 mL of the mixed solution were injected into the radial artery through the sheath. Through the sheath, a 120 cm Cobra catheter (Terumo) premounted with a 150 cm hydrophilic guidewire (Terumo) was inserted. When passing through the upper arm, the "guidewire goes with catheter" technique was adopted to avoid fluoroscopy. The guidewire was pushed about 10 cm ahead of distal end of the catheter with no resistance. Then the catheter was advanced and the proximal end of the guidewire was observed. If the guidewire moved with the catheter, it indicated no resistance. It should reach the subclavian artery when about 50-60 cm of the catheter had been pushed into the sheath. If the guidewire did not move with the catheter, it showed that the guidewire encountered resistance, entering into a small branch or encountering radial loop. In this instance, the guidewire was gently manipulated until there is no resistance and the

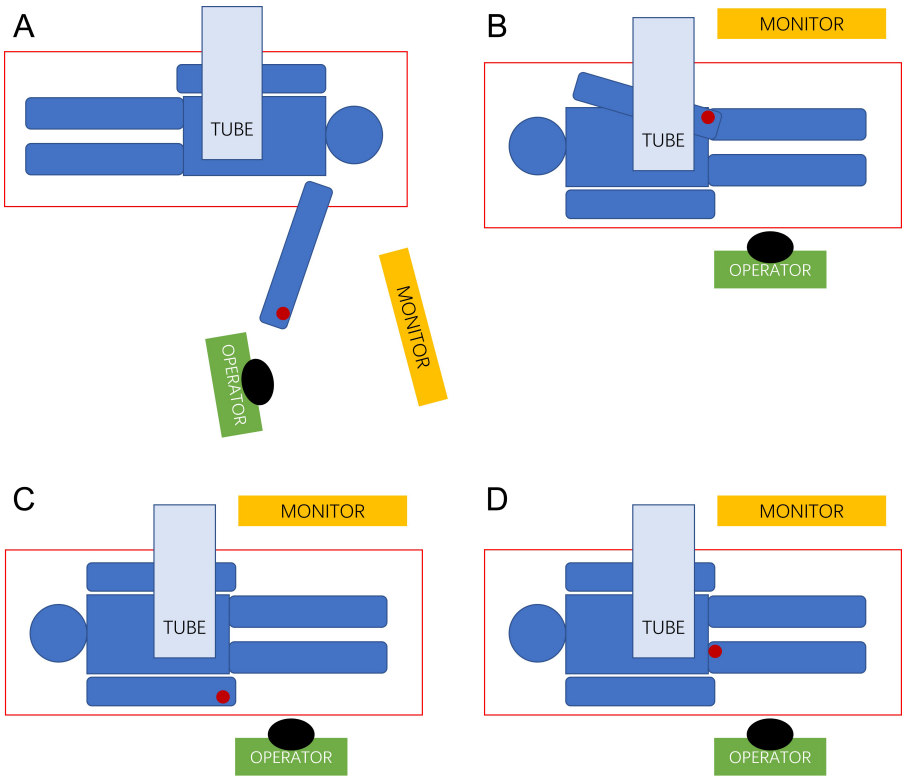

Figure 1. a-d. Different positions of patients and the operator during transarterial chemoembolization (TACE). **(a)** The patient was placed opposite to the conventional transfemoral access (TFA) position (foot-first), and the left upper arm was abducted on the hand placement plate at 70°-90°. The operator stood on the left side of the patient and punctured the left radial artery. **(b)** Patient's position was the same as that of the conventional TFA (head first), and the left palm was placed upward on the left groin. The operator stood on the right side of the patient and punctured the left radial artery. **(c)** Patient's position was the same as that of conventional TFA (head first), and the operator stood on the right side of the patient and punctured the right radial artery. **(d)** Patient was placed in the conventional TFA position, and the operator punctured the right femoral artery.

catheter was advanced again. If resistance persisted after several attempts, angiography and fluoroscopy were performed to help catheterize through the upper arm. Under fluoroscopy, the catheter was advanced into the descending aorta through the aortic arch. Catheterization and angiography of the celiac trunk and the mesenteric artery and sometimes the inferior phrenic artery were performed. Superselective catheterization of the tumor-feeding arteries was carried out with a 135 or 150 cm long 2.8 F microcatheter (Boston Scientific Corporation). Chemoembolization was performed with the emulsion of chemotherapeutic drugs and iodized oil injection (Lipiodol), followed by gelatin sponge particles. After embolization, the catheter was removed. Mixed solution of 5 mL was injected into the radial artery sheath before it was removed. Patent hemostasis was achieved using a WORK Radial Tourniquet (Hangzhou Shanyou Medical Equipment Co., Ltd.) for 1.5 hours and up to 2 hours for patients with coagulation disorders and thrombocytopenia.

TFA: Under local anesthesia, the right femoral artery was punctured and a 5 F femoral artery sheath (Terumo) was inserted. A 5 F Rosch Hepatic catheter was used to catheterize the celiac trunk and the mesenteric artery and sometimes the inferior artery. After angiography, superselective catheterization of the tumor-feeding arteries was carried out with a 135 cm long 2.8 F microcatheter (Boston Scientific Corporation). Chemoembolization was performed as described above. The sheath was pulled out and hemostasis was achieved with a WORK Femoral Tourniquet (Hangzhou Shanyou Medical Equipment Co., Ltd.) for 24 hours.

Technical evaluation

The clinical baseline characteristics of patients were recorded, including sex, age, height, weight, and body mass index (BMI). The baseline characteristics of their tumors were also recorded, including the diameter of the maximum tumor, number of tumors, extrahepatic metastasis, vascular invasion, and Barcelona clinic liver cancer stage. The procedural parameters including fluoroscopy time (FT), dose–area product (DAP), and air kerma (AK) were obtained from the DSA machine after each procedure. The effective radiation dose of each part of the operator was measured by TLD and then the normalized radiation dose (the effective radiation dose received on each body part of the operator per second) was calculated by dividing the radiation dose received on each part of the operator by FT. The TLD value was measured using RGD-3B. The clinical and tumor baseline characteristics, procedural parameters, radiation dose, and normalized radiation dose were compared among groups.

Statistical methods

The continuous data among the groups that did not conform to normal distribution were expressed as median (interquartile range) and were compared by the Kruskal–Wallis test. The data that conformed to normal distribution were expressed as mean (standard deviation) and were tested using one-way analysis of variance. The R × C chi-square test was used to compare classified variables among the groups. In pairwise comparison, the *P* value was corrected by Bonferroni correction. Statistical Package for the Social Sciences 22.0 (IBM Corp.) was used for data analysis. A 2-sided *P* value <.05 indicated a statistically significant difference.

Results

The clinical and tumor baseline characteristics of the patients in the 4 groups are shown in Table 1. A total of 120 patients were included (98 men and 22 women), with an age of 58.2 ± 9.1 years, height of 168.0 (163.0-172.0) cm, weight of 65 (60-70) kg, and BMI of 23.2 ± 2.9 kg/m^2. No significant difference was observed in clinical and tumor baseline characteristics between groups.

The FT, DAP, and AK of the 4 groups are shown in Table 2. The FT was 10.1 (6.9-16.2) minutes in group A, 10.0 (7.2-15.9) minutes in group B, 11.2 (7.3-16.8) minutes in group C, and 13.3 (6.5-19.9) minutes in group D, with no statistically significant difference among the groups (*P*=.96). The DAP was 159.7 (120.2-292.1) Gy · cm^2 in group A, 200.5 (99.7-312.2) Gy · cm^2 in group B, 239.8

Table 1. Baseline characteristics of patients

	Group A	Group B	Group C	Group D	*P*
Clinical characteristics					
Sex, n (%)					.78
Male	23 (76.7)	24 (80.0)	25 (83.3)	26 (86.6)	
Female	7 (23.3)	6 (20.0)	5 (16.7)	4 (13.4)	
Age (year), mean ± SD	56.4 ± 9.0	57.5 ± 8.4	57.4 ± 8.1	61.6 ± 10.4	.12
Height (cm), median (IQR)	168.0 (162.5-170.8)	168.0 (161.8-172.0)	169.0 (162.3-172.3)	168.5 (165.0-172.0)	.92
Weight (kg), median (IQR)	60.5 (57.3-68.0)	62.5 (57.8-72.3)	66.5 (60.0-71.3)	65.0 (61.5-70.0)	.29
BMI	22.6 ± 3.0	23.0 ± 2.8	23.7 ± 3.2	23.6 ± 2.4	.40
Characteristics of tumors					
Maximum diameter (cm)	3.0 (1.9-4.7)	3.3 (1.0-4.6)	2.6 (1.4-4.3)	3.3 (1.9-5.0)	.86
Number of tumors, n (%)					
1	5 (16.7)	10 (33.3)	13 (43.3)	15 (55.6)	.12
2	8 (26.7)	5 (16.7)	3 (10.0)	4 (14.8)	
3	6 (20.0)	6 (20.0)	6 (20.0)	6 (22.2)	
>3	11 (36.6)	9 (30.0)	8 (26.7)	2 (7.4)	
Extrahepatic metastasis, n (%)					.45
Yes	3 (10.0)	6 (20.0)	4 (13.3)	1 (3.3)	
No	27 (90.0)	24 (80.0)	26 (86.7)	29 (96.7)	
Vascular invasion, n (%)					.14
Yes	5 (16.7)	0 (0.0)	3 (10.0)	2 (6.7)	
No	25 (83.3)	30 (100.0)	27 (90.0)	28 (93.3)	
BCLC stage, n (%)					.99
A	17 (56.7)	16 (53.3)	14 (46.7)	16 (53.3)	
B	8 (26.7)	8 (26.7)	10 (25.9)	9 (30.0)	
C	5 (16.6)	6 (20.0)	6 (20.0)	5 (16.7)	

SD, standard deviation; IQR, interquartile range; BCLC, Barcelona clinic liver cancer score.

(140.1-317.8) Gy · cm^2 in group C, and 221.3 (188.3-355) Gy · cm^2 in group D, respectively, with no statistically significant difference among the groups ($P = .08$). The AK was 400.6 (306.5-632.9) mGy in group A, 507.3 (247.3-721.1) mGy in group B, 646.1 (388.1-821.6) mGy in group C, and 611.4 (419.2-863.6) mGy in group D, with no statistically significant difference among the groups ($P = .09$).

In all patients, the average effective radiation doses received by the operator were 1.2 (1.2-3.7) × 10^{-2} μSv on the head, 2.9 (1.2-4.5) × 10^{-2} μSv on the thyroid, 4.7 (2.7-8.2) × 10^{-2} μSv on the chest, 6.7 (2.8-12.6) × 10^{-2} μSv on the pelvic cavity, 6.6 (3.8-10.7) × 10^{-2} μSv on the left wrist, 1.2 (1.2-3.3) × 10^{-2} μSv on the right wrist, and 1.2 (1.2-2.5) × 10^{-2} μSv on the feet, as shown in Figure 2.

The effective radiation doses and the normalized radiation doses on each part of the operator in the 4 groups are shown in Table 3. Statistically significant differences were found in the effective radiation doses received by the operator on the pelvic cavity ($P = .03$) and right wrist ($P < .01$) and also the total doses ($P = .05$). In group C, the radiation doses received on the pelvic cavity, the right wrist, and total radiation doses were relatively highest. After normalization, the radiation doses on different parts of each group were compared, revealing statistically significant differences in the radiation doses received on the thyroid, chest, left wrist, right wrist, pelvic cavity, and the total doses among the groups ($P < .05$). The radiation doses received by the operator on the aforementioned parts in group A have a lower trend, while those in group C have a

Table 2. Procedural parameters in groups

	Group A	Group B	Group C	Group D	*P*
FT (minutes)	10.1 (6.9-16.2)	10.0 (7.2-15.9)	11.2 (7.3-16.8)	13.3 (6.5-19.9)	.96
DAP (Gy · cm^2)	159.7 (120.2-292.1)	200.5 (99.7-312.2)	239.8 (140.1-317.8)	221.3 (188.3-350.4)	.08
AK (mGy)	400.6 (306.5-632.9)	507.3 (247.3-721.1)	646.1 (388.1-821.6)	611.4 (419.2-863.6)	.09

FT, fluoroscopy time; DAP, dose–area product; AK, air kerma.

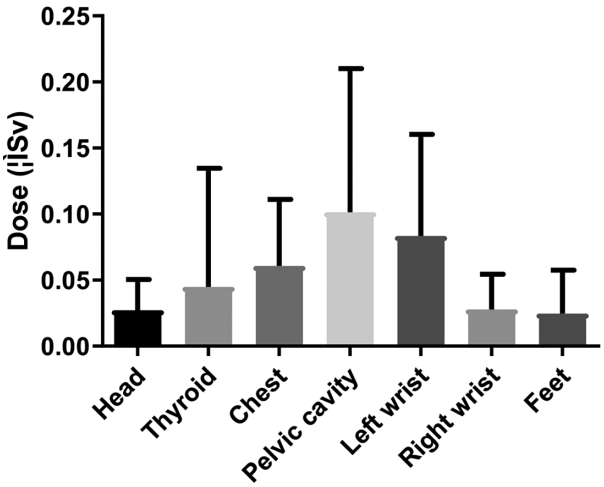

Figure 2. Effective radiation doses received on each part of the operator.

higher trend (Figure 3). The radiation doses on the right wrist of the operator in group B were lower than that in group C, while the radiation doses on the left wrist and right wrist and the total doses received by the operator in group D were lower than those in group C.

Discussion

This study evaluated radiation doses received by the operator in TACE via TRA and TFA when patients were placed in different positions. Although the total FT, DAP, and AK in TACE via TRA and via TFA were similar when patients were placed in the 4 common positions, statistically significant differences were found in the radiation doses received by the operators. The radiation doses received by the operator per second on the thyroid, chest, left wrist, right wrist, pelvic cavity, and the total doses were lower in group A but higher in group C.

At present, different centers place patients in different positions and choose to puncture in the left or the right hand. No study has suggested a position that could expose the operator to lower radiation doses. A small sample size study by Yamada et al.[13] concluded that the radiation doses received by the operator in TACE via TRA were lower than that in TACE via TFA, which was mainly due to the location of radiation shielding and the long distance between the operator and the radiation source. In their study, the patients were placed in the same position as in group A of the present study, and our results confirmed their study. According to the 3 elements of external radiation protection (distance, time, and shielding), our results have shown no significant difference in the FT. During the procedure, the same lead baffle under the bed and the movable lead glass baffle were used for shielding, and the same operator stood at the same position for effective shielding. This might be due to the distance as following factors: (1) patients in group A were placed in the foot-first position with the left upper arm abducted, the puncture point was via the left TRA, and the operator stood at the far end of their left hand, which was farther away from the operating table and the tube. Patients in groups B, C, and D were placed in the conventional position, the operator stood beside the operating table, and the operator in group B had to lean over the patient, relatively closer to the radiation source. (2) TACE was performed at the distal end of the catheter. The TRA catheter passed through relatively long blood vessels. When the 120 cm catheter was selected, the part of the catheter outside the arterial sheath was shorter than that of the Rosch Hepatic catheter used in TACE via TFA. When the microcatheter was used, the part of the microcatheter exposed was shorter. In groups B and C in which the patients were placed in the conventional position, the operator was closer to the tube than the femoral artery.

In most previous studies, radiation dosimeters were often worn on the chest, left wrist, and eye level. Sciahbasi et al.[18] believed that the movable baffle in the interventional operation effectively reduced the radiation dose received on the operator's head, especially on the left side of the head, with a reduction of 97%. Meanwhile, the lead glass baffle effectively reduced the radiation on the upper body, but it had no definite effect on the pelvic cavity; the radiation dose on the pelvic cavity was significantly higher than that on the chest.[19] The present study confirmed this view by measuring the radiation dose on various body parts of the operator. The radiation dose in the pelvic cavity and left wrist was believed to be

Table 3. Radiation doses received by the operator

	Group A	Group B	Group C	Group D	*P*
Radiation doses ($\times 10^{-2}$ μSv)					
Head	1.2 (1.2-3.1)	1.2 (1.2-3.2)	1.2 (1.2-6.0)	1.2 (1.2-4.8)	.50
Thyroid	1.9 (1.2-4.2)	2.4 (1.2-4.6)	3.6 (1.5-7.1)	1.2 (1.2-4.1)	.19
Chest	3.6 (1.2-5.9)	3.5 (1.2-7.5)	5.8 (3.5-9.7)	4.7 (2.5-8.1)	.14
Pelvic cavity	5.1 (2.5-8.6)	5.8 (1.2-12.4)	9.8 (6.0-16.2)	6.2 (2.0-11.5)	.03
Left wrist	5.9 (1.2-9.7)	7.5 (2.7-10.9)	7.4 (4.3-13.3)	4.9 (1.2-9.2)	.17
Right wrist	1.2 (1.2-2.8)	1.2 (1.2-2.5)	3.6 (1.2-6.3)	1.2 (1.2-1.8)	<.01
Feet	1.2 (1.2-3.6)	1.2 (1.2-1.2)	1.2 (1.2-2.5)	1.2 (1.2-1.2)	.14
Total doses	23.0 (12.3-34.6)	31.1 (13.3-54.2)	38.7 (23.5-61.3)	27.3 (18.1-41.1)	.05
Normalized radiation doses ($\times 10^{-5}$ μSv × s^{-1})					
Head	2.9 (1.9-3.9)	3.2 (2.2-5.2)	3.7 (2.2-6.8)	3.7 (2.7-5.4)	.36
Thyroid	3.5 (2.6-4.6)	5.1 (2.5-7.6)	6.8 (3.1-10.1)	4.7 (3.0-6.7)	.02
Chest	4.3 (2.9-7.8)	8.1 (4.4-11.8)	11.2 (6.2-17.0)	7.7 (4.5-10.5)	<.01
Pelvic cavity	6.0 (3.1-15.8)	10.2 (4.6-17.8)	16.1 (10.4-23.4)	9.4 (6.0-14.4)	<.01
Left wrist	7.2 (3.8-12.4)	10.8 (7.4-17.9)	12.4 (8.0-19.0)	7.3 (5.4-10.6)	<.01
Right wrist	2.8 (1.7-3.7)	3.0 (1.9-4.4)	5.5 (3.1-9.0)	2.6 (1.2-5.7)	<.01
Feet	3.1 (2.4-4.4)	2.6 (1.5-4.4)	2.3 (1.4-4.0)	2.5 (1.2-5.7)	.27
Total doses	32.2 (21.9-46.2)	50.7 (33.8-65.5)	68.3 (35.9-85.0)	39.0 (27.6-61.5)	<.01

Data are presented as median (interquartile range).

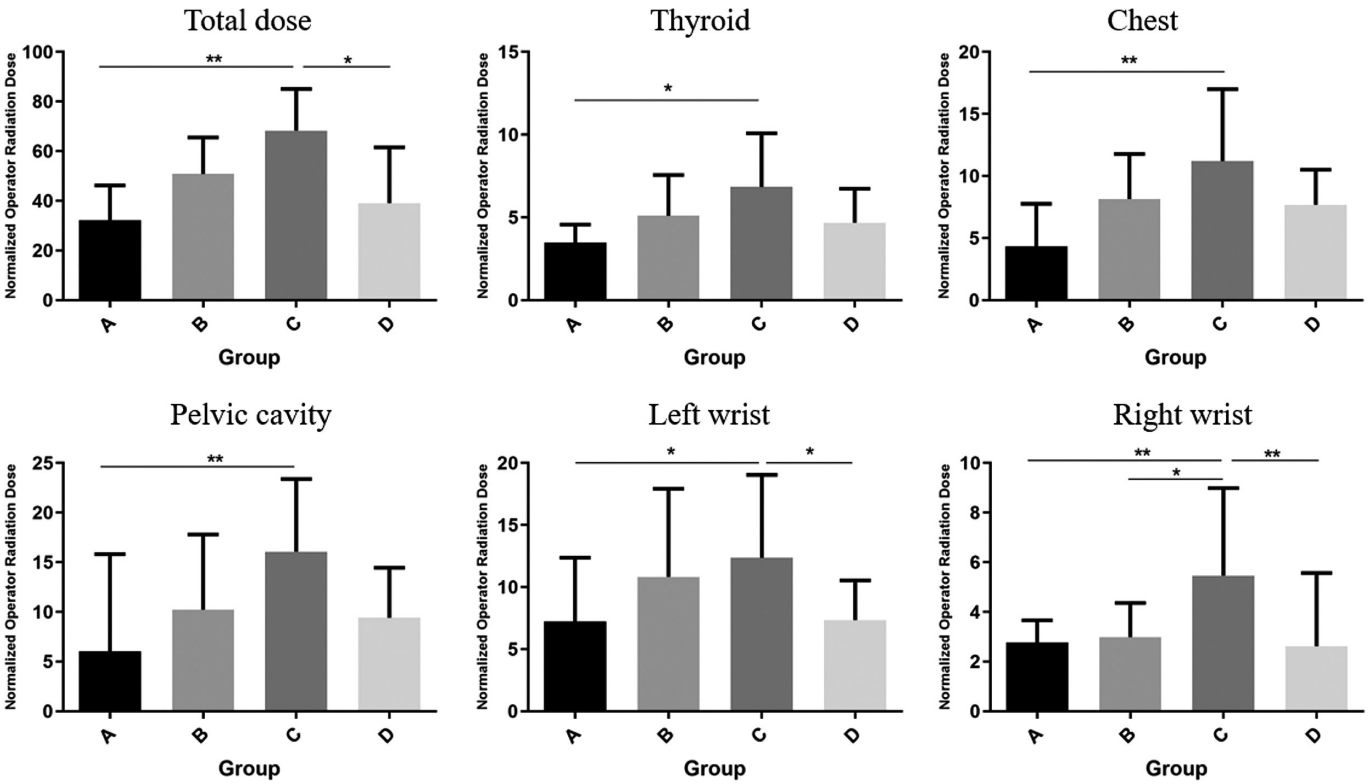

Figure 3. Normalized radiation doses received on each part of the operator. $^{*}P < .05$ and $^{**}P < .01$ indicate differences among the groups.

significantly higher than that in other parts of the body, mainly because the pelvic cavity and the left wrist were closer to the radiation source and the baffle could not shield the radiation effectively.

This study had certain limitations. First, this was a single-center study with a limited number of patients. Different centers with different DSA machines and more patients might have led to different results. Second, in this study, although the radiation dose received by the operator when patients were placed in different positions was statistically significant, the absolute value of the difference was low. However, according to the non-threshold principle of radiation protection, no safe dose was suggested. It was demonstrated that the lower the radiation dose, the lower the risk.[20] Third, the positions used in this study are most commonly used in non-coronary interventional therapy.[13-17] More position combinations could be attempted, for example, patients are put in conventional head-first position and operators stand on the left side, with the C-arm and the monitor turned to the opposite side. Finally, all the procedures were performed by 1 operator in this study. Different operators with different heights and procedural habits may affect the results.[21] A large sample multicenter study with different operators is required.

In conclusion, no statistically significant differences were observed in the FT, DAP, and AK in TACE via TRA when patients were placed in different positions. However, a statistically significant difference was found in the effective radiation dose received by the operator. The dose received by the operator in group A was lower, while the dose in group C was higher. TACE via the left TRA, with patients placed in the abduction position, might effectively reduce the radiation dose received by the operator and the radiation risk.

Financial disclosure

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Conflict of interest disclosure

The authors declared no conflicts of interest.

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