

Impact of Obesity on Overall Radiation Exposure for Patients Who Underwent Radiofrequency Ablation of Atrial Fibrillation



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Patients who underwent radiofrequency ablation of atrial fibrillation are exposed to X-rays not only during the procedure but also during the preprocedural computed tomography. No study has investigated the cumulative effective dose received by patients who underwent atrial fibrillation ablation and identified factors influencing this dose. We aimed to evaluate the overall exposure to ionizing radiation in patients who underwent radiofrequency ablation of atrial fibrillation. The secondary objective was to estimate the impact of obesity on this exposure. All patients who underwent a first attempt of radiofrequency ablation of atrial fibrillation in our center over a 21 months period were included. Dosimetric indicators from preprocedural computed tomography and the ablation procedure were collected and converted into an effective dose. A total of 144 radiofrequency ablation of atrial fibrillation were included. The mean cumulative effective dose was 11.4 mSv, and 82% of the dose was from the computed tomography. Obese patients received a dose that was 75% higher than normal-weight patients, and this increase remained significant by multivariate analysis. In conclusion, overall exposure to ionizing radiation for patients who underwent radiofrequency ablation of atrial fibrillation seems acceptable, and the majority of the overall effective dose comes from the computed tomography. Obese patients are exposed to a 75% higher dose than normal-weight patients. © 2019 Elsevier Inc. All rights reserved. (Am J Cardiol 2019;124:1213–1217)

Interventional cardiology, in constant evolution for several decades, now enables to manage a wide range of diseases minimally invasively but effectively. These interventions have in common to be performed under X-ray guidance, and sometimes to require, like transcatheter aortic valve replacement, the realization of one or more irradiating procedures during the preintervention work-up. Since the advent of 3D cardiac mapping systems, performing radiofrequency (RF) ablation of atrial fibrillation (AF) leads to perform an Electrocardiogram (ECG)-gated synchronized computed tomography (CT) scan upstream the procedure. Because patients who underwent AF ablation are generally young, they are likely to experience an increase in the radiation-induced cancer risk after RF ablation of AF.^{1,2} In this context, study of the overall exposure to ionizing radiation (including preprocedural CT and the procedure itself) is increasingly important, but existing study has only investigated the X-ray exposure during the ablation procedure.^{3–6} Moreover, studying obesity in the context of AF ablation is important as it affects the rate of procedural success,⁷ and it has been shown previously that obesity was a major determinant of X-ray exposure in patients who underwent AF ablation. However, this study was conducted at a time when

3D cardiac mapping systems was not developed for this indication, and therefore considered only the radiation exposure during the ablation procedure.⁴ The main objective of our study was therefore to evaluate the overall exposure to ionizing radiation of patients who underwent RF ablation of AF. The secondary objective was to estimate the impact of obesity on this exposure.

Methods

This was a retrospective cohort study, including all patients who underwent a first attempt of RF ablation of AF in our center from January 2017 to September 2018. Clinical, echocardiographic, biologic, and dosimetric data were retrospectively compiled using medical records and the Dosimetry Archiving and Communication System (DACS) of our center (Dosimetry Archiving and Communication System, Medsquare, Paris, France). All patients have given, at the time of their hospitalization, their informed consent for an anonymous retrospective use of their medical data.

RF ablation procedures were all performed with the same 3D cardiac mapping system (CARTO3 software, Biosense Webster, Johnson & Johnson, Irvine), under general anesthesia, with 3 venous femoral sheaths of 6Fr, 8Fr, and 9Fr, with respectively a reference decapolar diagnostic catheter positioned in the coronary sinus, a deflectable circular duodecapolar catheter with variable diameter for anatomical and electrical mapping of the left atrium and the pulmonary-veins (PV; LASSO NAV, Biosense Webster, Johnson & Johnson, Irvine), and a 3.5 mm irrigated RF catheter (THERMOCOOL SMART TOUCH, Biosense

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Webster, Johnson & Johnson, Irvine). Transseptal puncture was performed under transoesophageal echocardiography and fluoroscopy guidance. PV ostia were localized thanks to the CT scan and the intracardiac impedance. No PV angiograms were performed before the ablation. Electrical and anatomical mapping of the left atrium was supported by the FAM software (Fast Activation Mapping, Biosense Webster, Johnson & Johnson, Irvine). PV isolation was performed for all procedures, associated with an atrial electrical defragmentation for persistent AF not converted to sinus rhythm, atrial tachycardia, or atrial flutter after PV isolation. Focal atrial tachycardia and atrial flutter occurring during procedure were mapped and ablated. If a common right atrial flutter has been previously documented or was documented during ablation procedure, cavo-tricuspid isthmus was treated by RF ablation. Validation of the isolation of PV was performed by the demonstration of an entry and an exit block on each pulmonary vein, 30 minutes after the last RF application. Linear lesions were validating by differential pacing.

The same cardiologist, with an experience of more than 300 RF ablation of AF, performed all the ablation procedures in a single electrophysiology laboratory equipped with the Arcadis Avantic system (Siemens Healthcare, Erlangen, Germany) in service since January 2011 (image intensifier with a frame rate of 4 fps and 33 cm size of field). The equipment undergoes half-yearly control by the manufacturer, and annual external quality control. The electrophysiology laboratory is equipped with lead screens and table drapes with 0.5 mm Pb equivalent used consistently. All operators wear a leaded apron and a thyroid shield with 0.5 mm Pb equivalent. They also have a passive dosimeter with quarterly statements (Landauer, Glenwood) and an active dosimeter (APVL, Saint-Cyr-sur-Loire, France). A fellow and a nurse were present for all procedures. A retrospectively ECG-gated synchronized angiographic CT scan from the aortic arch to a few centimeters under the diaphragmatic cupolas and focused on the left atrium was systematically performed on a dual energy CT Discovery 750 HD scanner (General Electrics, Massachusetts, in service since April 2012).

Overweight was defined as a body mass index (BMI) from 25 to 30 kg/m² and obesity was defined as a BMI greater than or equal to 30 kg/m². "PVI alone" corresponded to the PV isolation (PVI) without ablation of complex fractionated electrograms or linear ablation, whereas "PVI+" corresponded to PVI with at least one other ablation (including cavo-tricuspid isthmus ablation). Left atrium volume was calculated basis on the three-dimensional CT reconstruction. In patients with paroxysmal AF or persistent AF in sinus rhythm at the time of ablation, success was defined as a successful PVI. In patients in spontaneous AF at the time of ablation, success was defined as a successful PVI associated with a restoration of sinus rhythm (without electrical cardioversion) or with a conversion in an organized atrial tachycardia.

Depending of the type of irradiating procedure, 2 dose estimators are provided by the apparatus. To homogenize doses and to enable calculation of a cumulative dose, we converted these estimators into an effective dose (ED). The dose area product (DAP), expressed in cGy.cm², used

in cardiology and interventional radiology, is a synthetic dose indicator expressing the total amount of energy delivered to the patient. A simplified formula makes it possible to estimate the ED from the DAP: ED (mSv) = DAP (cGy.cm²) × 0.002 (mSv/cGy.cm²).^{8,9} CT uses another estimator determined by the anatomical region studied, the dose length product (DLP), expressed in mGy.cm. A coefficient enables conversion of DLP to ED according to the anatomical region, and the following formula proposed by Christner et al directly converts DLP into ED: ED (mSv) = DLP (mGy.cm) × 0.021 (mSv/mGy.cm).⁸⁻¹⁰ The primary end point was the cumulative ED, calculated by summing ED received during the preprocedural CT and during the ablation procedure.

Quantitative variables are described as median and [interquartile range] or mean ± standard deviation and qualitative variables as number (percentage). Quantitative variables were compared using nonparametric Kruskal-Wallis test. Multiple comparisons between normal weight, overweight, and obese patients were performed using the Dwass, Steel, Critchlow-Fligner analysis. Qualitative variables were compared using Fisher's exact. Relations between quantitative variables were investigated using simple linear regression. Multivariate analysis was performed using a generalized linear regression including all variables related to the primary endpoint with a p value <0.10 by univariate analysis. In view of the risk of collinearity between the left atrial volume and the pattern of AF (paroxysmal or persistent), only the variable most significantly related to the overall ED by univariate analysis was introduced in the multivariate model. All analyses were performed using SPSS version 21 (IBM SPSS Statistics, Chicago). A p value <0.05 was considered statistically significant; all tests were 2-sided.

Results

A total of 144 patients who underwent a first attempt of RF ablation of AF in our center over the 21 months period were included. The overall ED ranged from 4 to 42.3 mSv, with an average of 11.4 mSv. Eighty two percent of the exposure was related to the preprocedural CT, with an ED of 9.4 ± 5.8 and 2 ± 2 mSv for the CT and the ablation procedure respectively.

Forty three percent of the patients were overweight and 33% were obese. [Table 1](#) presents the comparison of patients according to their BMI. Median overall ED of overweight and obese patients was respectively 23% (p=0.2) and 75% (p=0.007) higher than normal-weight patients ([Figure 1](#)). Besides BMI, overall ED was significantly associated with the patient sex (p=0.005), the X-ray time (p=0.001), the type of AF (paroxysmal or persistent) (p=0.01), the left atrial volume (p=0.001) but was not associated with PVI alone (p=0.09), hypertension (p=0.13), diabetes (p=0.4) or patient age (p=0.9). After adjustment, BMI (p=0.009) and X-ray time (p=0.004) remained significantly associated with the overall ED ([Table 2](#)).

Procedural success was strongly related to the type of AF, since the rate of successful ablation was of 100% of patients with paroxysmal AF or persistent AF in sinus

Table 1

Comparison of population characteristics between normal-weight (BMI <25 kg/m²), overweight (25 kg/m² ≤ BMI <30 kg/m²), and obese patients (BMI ≥30 kg/m²)

Variables	Overall population (n = 144)	Normal-weight (n = 34)	Overweight (n = 62)	Obese (n = 48)	Obese vs Normal- weight p value*	Overall p value [†]
Population:						
Age (years)	60 [53-66]	60 [48-67]	60 [54-65]	59 [52-66]	0.7	0.9
Women	30 (21%)	9 (26%)	9 (15%)	12 (25%)	1	0.2
Hypertension	60 (42%)	9 (26%)	27 (44%)	24 (50%)	0.04	0.1
Diabetes	12 (8%)	1 (3%)	6 (10%)	5 (10%)	0.4	0.5
Heart failure	15 (10%)	2 (6%)	6 (10%)	7 (14%)	0.3	0.5
CHA ₂ DS ₂ -VASc:						
0	40 (28%)	11 (32%)	17 (28%)	12 (25%)		
1	52 (36%)	11 (32%)	26 (42%)	15 (31%)	0.8	0.9
2	33 (23%)	8 (24%)	12 (19%)	13 (27%)		
>2	19 (13%)	4 (12%)	7 (11%)	8 (17%)		
Left atrium volume (ml)	110 [92-145]	103 [90-135]	110 [95-140]	120 [98-170]	0.1	0.09
Atrial fibrillation:						
Paroxysmal	73 (51%)	23 (68%)	35 (56%)	15 (31%)	0.002	
Persistent	71 (49%)	11 (32%)	27 (44%)	33 (69%)		0.003
Procedural data:						
PVI alone	77 (54%)	18 (53%)	41 (66%)	18 (38%)	0.2	0.01
Procedural time (min)	125.4 [105-150]	126.9 [105.9-139.5]	125.4 [99.3-150]	127.2 [111.2-165]	0.4	0.3
Dosimetric data:						
Overall ED (mSv)	9.7 [7.1-13.8]	6.9 [5.3-12.1]	8.5 [7.1-11.2]	12.1 [9.9-16]	<0.001	<0.001
CT:						
DLP (mGy.cm)	384.5 [278.7-531.6]	244.7 [202.7-502.5]	340.9 [287.6-456.9]	450.9 [388.3-616.7]	<0.001	<0.001
ED (mSv)	8.1 [5.9-11.2]	5.1 [4.3-10.6]	7.2 [6-9.6]	9.5 [8.2-13]	<0.001	<0.001
AF ablation:						
DAP (cGy.cm ²)	699.4 [393.7-1232.4]	671.3 [354.1-671.3]	496.6 [293.1-979.4]	859.3 [475.3-1968.7]	0.2	0.006
ED (mSv)	1.4 [0.7-2.5]	1.3 [0.7-2.2]	1 [0.6-2]	1.7 [1-3.9]	0.2	0.006
X-ray time (min)	6.8 [4.5-10.5]	8.3 [5.4-12.5]	5.8 [3.7-8.6]	9 [4.8-11.1]	0.9	0.005

CT = computed tomography; DAP = dose area product; DLP = dose length product; ED = effective dose; PVI = pulmonary-veins isolation.

* Dwass, Steel, Critchlow-Fligner analysis (quantitative variables), and Fisher's exact test (qualitative variables).

[†] Kruskal-Wallis test (quantitative variables) and Fisher's exact test (qualitative variables).

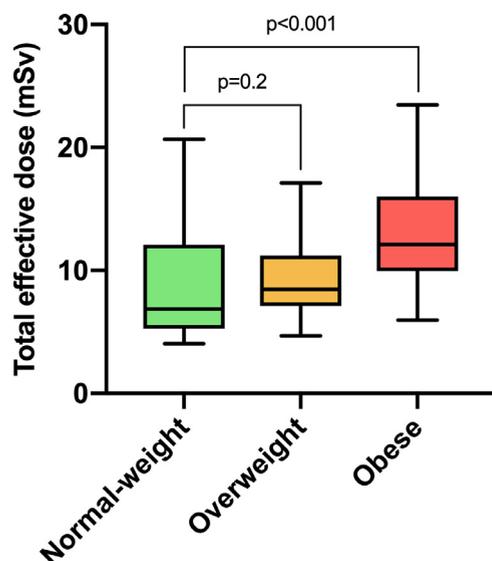


Figure 1. Box and whisker plots showing the distribution of the overall effective dose for normal-weight (BMI <25 kg/m²), overweight (25 kg/m² ≤ BMI <30 kg/m²) and obese patients (BMI ≥30 kg/m²). The boxes represent the median with the first and third quartiles, and the “whiskers” represent the upper and lower limits excluding the extreme values (Tukey's style).

rhythm at the time of ablation, whereas the success rate dropped to 49% in patients in spontaneous AF at the time of ablation ($p < 0.001$). In addition, success of ablation was related to BMI and left atrial volume ($p = 0.04$ and $p < 0.001$, respectively) but not to the DAP ($p = 0.7$) or the overall ED ($p = 0.8$).

Discussion

Our study, which is the first to consider the global exposure to ionizing radiation for patients who underwent a RF

Table 2

Multivariate analysis of the factors associated with the overall effective dose received by the patient

	Beta coefficient	Standard error	p value
X-ray time (per additional minute)	0.27	0.10	0.004
BMI (per additional kg/m ²)	0.27	0.11	0.009
Female (vs male)	-2.24	1.19	0.06
Left atrial volume (per additional ml)	0.03	0.01	0.06
PVI alone (vs PVI+)	0.15	1.01	0.9

AF = atrial fibrillation; PVI+ = pulmonary-veins isolation associated with one or several other ablations.

ablation of AF, found an overall ED of 11.4 mSv on average, which appears to be acceptable in relation to the reference standards of irradiating procedures performed in cardiology. Indeed, a standard ED of 22 mSv for a CRT implant and of 81 mSv for the angioplasty of a coronary chronic total occlusion have been reported.⁸ The advent of 3D cardiac mapping systems has significantly reduced the X-ray time during RF ablation of AF,¹¹ as evidenced by the small contribution of the ablation procedure itself to the overall ED (18% in average). However, X-ray time in our population seems to be smaller than what is usually described,¹² which may have an impact on our results.

Ector et al⁴ reported in 2007 the dosimetric characteristics of a cohort of 90 AF ablation procedures, at a time when 3D cardiac mapping systems were not developed for this indication. They reported an average ED of 22.4 mSv with an average X-ray time of 83 minutes. BMI was strongly associated with the ED, obese patients receiving more than 3 times the ED of normal-weight patients. The present study showed that the overall ED for obese patients was 75% higher than normal-weight patients, and therefore underlines that the impact of obesity on radiation exposure for patients who underwent a RF ablation of AF significantly decreased over the past decade.

Finally, our findings confirm that technology evolutions (such as 3D cardiac mapping systems and contact force sensing catheters) have dramatically reduced the radiation exposure and the X-ray time of patients who underwent RF ablation of AF^{5,11} (respectively 2 mSv and 8.2 minutes of X-ray in our study). It also highlights that it was obtained at the cost of an important radiation exposure at the time of the preprocedural CT (82% of the overall dose in our study). However, the global ED remains clearly lower than the ED of ablation procedures performed without mapping of the left atrium.^{4,6} In addition, preprocedural CT allows to describe PV anatomy (PV size, supernumerary, or accessory PV) and to identify a potential atrial thrombus, and thus improves procedural safety. The shift in the relative proportions of ionizing radiation received from preprocedural CT and the procedure itself over the years (previously, more derived during the procedure, now more derived from the CT scan), should encourage to replace preprocedural CT by gadolinium-enhanced cardiac magnetic resonance imaging³ or ultrasound (using the CartoSound feature integrated with electroanatomic mapping system) for determining left atrial anatomy, neither of which use any ionizing radiation.

Due to the single-center design of our study, some factors may affect generalizability of our results, including the use of transoesophageal echocardiography for transseptal puncture. Some labs use only fluoroscopy for transseptal puncture, thus changing the ratio of CT to ablation ration. The use of higher frame rates than 4 fps would change the ratio also. The fact that fluoroscopy time was lowest in overweight patients compared with the other 2 cohorts was likely due to small sample size rather than a biologically feasible explanation and constitutes a limitation of our study. However, we present complete dosimetric data from a homogeneous cohort of patients who underwent RF ablation of AF. We thus provide an estimation of the overall ED received by the

patients, which has never previously been reported, to the best of our knowledge.

Patients who underwent RF ablation of AF are exposed to an average overall ED of 11.4 mSv and 82% of the exposure is related to the preprocedural CT, highlighting the shift in the relative proportions of ionizing radiation received from preprocedural CT and the procedure itself over the years. Impact of obesity on overall exposure to ionizing radiation, which was previously considered to be major with a dose increase of more than 300% for obese patients, seems finally revealed to be moderate. Indeed, the overall ED for obese patients was only 75% higher than normal-weight patients.

Disclosures

The authors have no conflicts of interest to disclose.

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