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# Effect of fluoroscopy frame rate on radiation exposure and in-hospital outcomes in three-dimensional electroanatomic mapping guided procedures

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## Abstract

**Background:** Fluoroscopic imaging involves exposure of the patients and the laboratory staff to ionizing radiation. One of the strategies that reduce such exposure in an electrophysiology laboratory is using a three-dimensional electroanatomic mapping (3D EAM) system for performing these procedures. In this analysis, we have analyzed the effect of fluoroscopy frame rate on the radiation exposure and in-hospital outcomes in ablation procedures performed under 3D EAM guidance.

**Methods:** We retrospectively analyzed all the ablation procedures performed under 3D EAM guidance at our institute from September 2015 to December 2018. The procedures were divided into two groups based on whether the procedures were performed before (pre) or after (post) January 26, 2018. After January 2018, fluoroscopy was used at a frame rate of 3.75 frames per second (fps). Radiation exposure indices and in-hospital outcomes were compared between the two groups.

**Results:** Ablation procedures included in the analysis were ventricular arrhythmias (n = 192), atrial flutter (115), atrial tachycardia (AT) (43), and atrial fibrillation (AF) (30). Over the study period, there was a significant reduction in procedure time, fluoroscopy time, dose area product, and effective dose (ED) ($P < .001$). Except for AT and AF ablation procedures, there was a significant reduction in the radiation exposure indices when the "post" group was compared with the "pre" group ($P \leq .02$). The decrease in the frame rate had no significant effect on in-hospital outcomes.

**Conclusion:** The use of 3D EAM combined with decreasing the fluoroscopy frame rate significantly reduced the total radiation exposure without adversely affecting in-hospital outcomes.

KEYWORDS

atrial flutter, effective dose, radiation exposure, three-dimensional electroanatomic mapping, ventricular tachycardia

## 1 | INTRODUCTION

Electrophysiology procedures are commonly performed using fluoroscopy, which poses a risk of exposure to ionizing radiation in both patients and the laboratory staff.[1]

Exposure to ionizing radiation can have either a) deterministic effects (tissue reactions), for example, skin injury, cataract, etc, or b) stochastic effects, that is, carcinogenic and genetic effects.[2]

One of the strategies that help in reducing the exposure to these ionizing radiations during various electrophysiology procedures is the use of three-dimensional electroanatomic mapping (3D EAM). Although there has been an increase in the use of 3D EAMs and intracardiac echocardiography (ICE), the physicians continue to rely on fluoroscopy during these procedures.[2]

In the current analysis, we assessed the amount of radiation exposure in electrophysiological procedures performed with the help of the 3D EAM system and analyzed the effect of fluoroscopy frame rate on various radiation exposure indices. In-hospital outcomes were also compared between the two groups.

## 2 | OBJECTIVES

To study the effect of fluoroscopy frame rate on various radiation exposure indices of ablation procedures performed with the help of a 3D EAM system, and to study the effect of frame rate on in-hospital procedural outcomes.

## 3 | METHODS

We retrospectively analyzed data from September 2015 to December 2019 of all the procedures performed under 3D EAM guidance at our institute.

In our laboratory, before January 26, 2018, although there was no restriction on the frame rate, fluoroscopy was usually used at 7.5 frames per second (fps); after that date, fluoroscopy was used exclusively at a frame rate of 3.75 fps.

The data collected included age, sex, arrhythmia diagnosis, procedure, procedure time, fluoroscopy time, and dose area product (DAP). Procedures without these details were excluded from the analysis.

The procedure time was defined as the time from the administration of a local anesthetic agent to the removal of catheters from the patient's body.

All the procedures were performed in the same electrophysiology laboratory using the Philips Allura Xper FD 10 system (Philips Healthcare, Best, the Netherlands). Electroanatomic mapping was done using the Carto system (Biosense Webster, CA, USA).[2,3]

The effective dose (ED, in mSv) was derived from DAP values provided by the X-ray system by multiplying it with a conversion factor. The conversion factors used for adult males and females were 0.2 and 0.28, respectively. The conversion factors used for pediatric age groups were: 3.7 for neonates; 1.9 for children above 1 year of age; 1.0 for children above 5 years of age; 0.6 for children above 10 years of age; and 0.4 for children 15 to 20 years of age.[2]

Lifetime attributable risk (LAR) of cancer incidence and mortality was estimated by multiplying the ED that each patient received with 0.0001/mSv.[4]

In-hospital outcomes were divided into two groups: a) procedural success and b) complications.

Procedural success was defined as a) ventricular tachycardia (VT): noninduction of the clinical tachycardia at the end of the procedure, b) atrial flutter: noninduction of the tachycardia and bidirectional block across the critical isthmus, c) ventricular premature contraction (VPC): complete abolition, d) atrial tachycardia (AT): noninduction of clinical tachycardia, and e) atrial fibrillation (AF): isolation of all the pulmonary veins.

Complications were divided into two groups a) minor: access site bleeding and b) major: access site complications requiring surgical intervention, cardiac tamponade, stroke, AV block requiring permanent pacing, and phrenic nerve palsy.

The procedures were performed by four full-time operators with an experience of 21, 11, 6, and 4 years in interventional electrophysiology. Our institute has an active EP fellowship program running since 2009, and the principles of radiation safety in the catheterization laboratory are an essential part of the training program. The fellows are an integral part of the EP procedures carried out in our laboratory.

The data were summarized using standard descriptive statistics and presented as the arithmetic means or medians with range or standard deviation, as appropriate. The radiation exposure parameters and the procedure time over the study period were compared using the Kruskal-Wallis test. The effect of fluoroscopy frame rate over various parameters was compared using the Mann-Whitney U test. The level of significance was fixed at $P < .05$.

Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS), version 20.

Informed consent was obtained from all patients before the procedure, and they were informed that their data could be used for scientific purposes.

Institutional review board approval was not applied for this retrospective analysis.

## 4 | RESULTS

A total of 380 procedures were included in the analysis: VT: 148 (mean age: 43.2 ± 16; 80% males), atrial flutter: 115 (mean age: 52.8 ± 14; 69% males), VPCs: 44 (mean age 44.5 ± 15, 64% males), AT: 43 (mean age: 46.4 ± 17; 44% males), and AF: 30 (53.7 ± 12; 63% males).

The mean age of the patients was 47.5 ± 15.8 years. Two hundred and sixty-three of them (69.2%) were males.

VTs that were ablated were postmyocardial infarction scar VTs (n = 103), fascicular VT (n = 22), and idiopathic VT (21). One patient had cardiac sarcoidosis, and another patient had nonischemic cardiomyopathy.

Atrial flutter patients consisted mostly of cavotricuspid isthmus-dependent flutters (103).

## 5 | RADIATION INDICES

Table 1 shows year-wise trends in radiation indices of all the procedures. Table 2 shows the radiation indices before (pre) and after (post) fluoroscopy was used at a frame rate of 3.75 fps of all the procedures.

## 6 | IN-HOSPITAL PROCEDURAL OUTCOMES

Procedural success was 98% (168) in the pre group and 96% (200) in the post group (p-value 0.2).

Minor complications occurred in two patients in the pre group and four patients in the post group (p-value 0.6).

Only one major complication was documented in the entire cohort. One patient in the post group developed complete heart block after VT ablation and received a dual-chamber pacemaker in the postprocedure period. The patient had a bifascicular block in the preprocedure electrocardiogram and had an extensive septal scar on 3D EAM (Table 3).

## 7 | DISCUSSION

3D EAM has revolutionized the field of cardiac electrophysiology. These systems enable the operator to construct three-dimensional cardiac anatomy and visualize the catheters nonfluoroscopically.[5] There are three 3D EAM systems now in common clinical use: the Carto system (Biosense Webster, USA), the EnSite system (Abbott, USA), and the Rhythmia (Boston Scientific, USA).[6]

Over the years, we have seen a significant improvement in the technology of 3D EAM and the procedural skills of electrophysiologists, which has allowed for minimizing or eliminating the use of fluoroscopy during various electrophysiology procedures.[7,8] Minimizing radiation exposure during these procedures can minimize the risks, including malignancies, especially to the physicians and laboratory staff. There is enough evidence that minimizing or eliminating radiation use during electrophysiology procedures is safe and effective.[6-8]

In a prospective randomized study involving different catheter ablation procedures, the Carto system use resulted in a significant reduction in fluoroscopy time (9.3 vs 28.8 min, $P < .001$) and radiation dose (6.2 vs 20.8 Gray, $P = .003$).[7]

In the NO-PARTY trial, there was a decrease in the median DAP from 2036 to 278 cGy.cm$^2$ ($P < .00001$) using the Ensite NavX system. The EAM system also allowed for ablation of supraventricular tachycardias without the use of ionizing radiation in 72% of the patients.[8]

In a retrospective analysis, Razminia M et al found that limiting or completely eliminating the use of fluoroscopy during catheter ablation in almost 500 patients was safe with a very low complication rate of 1%.[9]

However, limiting or eliminating fluoroscopy during catheter ablation of various arrhythmias is a slow step-by-step learning process. During the learning phase of minimizing fluoroscopy use during the procedures, the physicians may still rely on fluoroscopy.[10] Even during procedures utilizing minimal or zero-fluoroscopy, there will be situations when physicians may need to use fluoroscopy for safety and efficacy issues.[9]

Thus, it is imperative even in the era of zero-fluoroscopy to evaluate and formulate the strategies that may further reduce the dose and exposure to radiation in the electrophysiology laboratory.

The reduction of fluoroscopy frame rate is one of the simplest ways to reduce radiation exposure in the laboratory as the radiation exposure is almost linearly related to the fluoroscopy frame rate. Decreasing the frame rate from 25 fps to 3 fps reduces radiation exposure by a factor of 8.[2]

Multiple studies have analyzed the effect of fluoroscopy frame rate (down to 2 fps) on radiation exposure in catheter ablation procedures.[11-14] These studies have shown that a decrease in the frame rate alone has resulted in a significant decrease in radiation exposure without affecting the clinical outcome. However, in a survey of European electrophysiologists, only 15% reported using fluoroscopy at a rate of 3 fps, and 17% did not know at what frame rate they used the fluoroscopy system,[15] and studies have shown that ionizing

**TABLE 1** Year-wise changes in radiation indices of all the procedures

| Year | Number | Procedure time (mins) | Fluoroscopy time (mins) | DAP (cGycm$^2$) | ED (mSv) | LAR, % |
|---|---|---|---|---|---|---|
| 2015 | 32 | 180 (145-233) | 34 (18-43) | 2034 (847-3801) | 4.8 (2.4-8.3) | 0.05 (0.02-0.08) |
| 2016 | 47 | 165 (120-210) | 19 (10-33) | 2270 (675-4025) | 5.7 (1.9-8.4) | 0.06 (0.02-0.08) |
| 2017 | 86 | 180 (150-248) | 33 (20-48) | 2447 (1358-4487) | 5.6 (3.5-11.0) | 0.06 (0.03-0.1) |
| 2018 | 93 | 140 (105-173) | 20 (15-30) | 1418 (936-2655) | 3.2 (2.1-5.8) | 0.03 (0.02-0.06) |
| 2019 | 122 | 150 (120-200) | 15 (9-24) | 1346 (691-2256) | 3.0 (1.6-5.2) | 0.03 (0.02-0.05) |
| All | 380 | 160 (120-210) | 21 (13-34) | 1701 (878-3077) | 4.0 (2.1-7.0) | 0.04 (0.07-0.02) |
| | *P*-value | <.001 | <.001 | <.001 | <.001 | <.001 |

**TABLE 2** Effect of fluoroscopy frame rate on various radiation indices

| | Number | Procedure time (mins) | Fluoroscopy time (mins) | DAP (cGycm$^2$) | ED (mSv) | LAR, % |
|---|---|---|---|---|---|---|
| All procedures | | | | | | |
| Pre | 171 | 180 (140-225) | 30 (18-43) | 2317 (1220-4225) | 5.3 (2.7-9.2) | 0.05 (0.03-0.09) |
| Post | 209 | 145(113-188) | 17(11-25) | 1406(774-2258) | 3.1(1.9-5.3) | 0.03 (0.02-0.05) |
| *P*-value | | <.001 | <.001 | <.001 | <.001 | <.001 |
| VT ablation procedures | | | | | | |
| Pre | 67 | 165 (134-225) | 27 (12-41) | 1487 (665-3137) | 4.1 (1.6-6.8) | 0.04 (0.02-0.07) |
| Post | 81 | 155 (120-195) | 15 (9-23) | 1115 (595-1816) | 2.5 (1.3-4.2) | 0.03 (0.01-0.04) |
| Total | 148 | 163 (125-210) | 18 (10-30) | 1265 (596-2342) | 3.0 (1.4-5.1) | 0.03 (0.01-0.05) |
| *P*-value | | .1 | <.001 | .03 | .005 | .005 |
| VPC ablation procedures | | | | | | |
| Pre | 15 | 160 (120-180) | 25 (16-42) | 2187 (945-6526) | 4.6 (2.4-13.1) | 0.05 (0.02-0.13) |
| Post | 29 | 90 (70-128) | 10 (6-20) | 1441 (446-2038) | 2.9 (1.1-4.2) | 0.03 (0.01-0.04) |
| Total | 44 | 120 (78-160) | 16 (7-26) | 1457 (648-3182) | 3.3 (1.4-6.7) | 0.03 (0.01-0.07) |
| *P*-value | | .002 | .001 | .03 | .02 | .02 |
| Atrial flutter ablation procedures | | | | | | |
| Pre | 43 | 180 (140-225) | 35 (24-45) | 2753 (2043-5608) | 5.9 (4.1-11.8) | 0.06 (0.04-0.12) |
| Post | 72 | 135 (106-180) | 22 (15-32) | 1572 (939-2898) | 3.4 (2.3-6.5) | 0.03 (0.02-0.06) |
| Total | 115 | 150 (120-210) | 27 (17-39) | 2162 (1146-3625) | 4.6 (2.5-8.7) | 0.05 (0.02-0.09) |
| *P*-value | | <.001 | <.001 | <.001 | <.001 | <.001 |
| AF ablation procedures | | | | | | |
| Pre | 22 | 225 (180-304) | 40 (25-57) | 4194 (2841-7355) | 8.7 (6.2-19.4) | 0.09 (0.06-0.2) |
| Post | 8 | 205 (161-278) | 32 (18-37) | 3528 (2090-5190) | 8.1 (4.6-13.1) | 0.08 (0.05-0.1) |
| Total | 30 | 210 (180-300) | 37 (21-48) | 4194 (2363-6762) | 8.5 (6.0-15.2) | 0.09 (0.06-0.15) |
| *P*-value | | .3 | .07 | .3 | .5 | .5 |
| AT ablation procedures | | | | | | |
| Pre | 24 | 173 (121-201) | 26 (15-35) | 2059 (850-2662) | 4.5(3.4-7.4) | 0.05 (0.03-0.07) |
| Post | 19 | 165 (145-225) | 17 (11-24) | 1412(993-2238) | 3.5 (2.3-5.7) | 0.04 (0.02-0.06) |
| Total | 43 | 165 (123-205) | 20 (14-30) | 1892 (886-2525) | 4.2 (2.7-6.1) | 0.04 (0.03-0.06) |
| *P*-value | | .6 | .05 | .2 | .1 | .1 |

radiation exposure awareness significantly decreases radiation exposure in the EP laboratory.[16]

In the current analysis, we found a significant decrease in radiation exposure indices such as fluoroscopy time, DAP, and ED across all the study period procedures.

The results of the current analysis are comparable to those of previously published studies (Table 4).

We believe that the main reasons for reducing radiation indices are a) decreased use of fluoroscopy, b) reduction in fluoroscopy frame rate when fluoroscopy was used, and c) reduction in the procedure time.

Other reasons that may have contributed to the decrease in radiation exposure indices are (a) avoidance of using cine exposure as much as possible; (b) frequent use of the fluoroscopy storage capability of the system whenever there was a need for the reference image, and (c) cine acquisitions were also taken at 3.75 fps, whenever possible.

The number of various electrophysiology procedures performed each year has consistently shown an upward trend. By utilizing the strategies of decreasing frame rate and total procedure time, the amount of exposure to radiation among the physicians and laboratory staff is expected to decrease significantly.

In our study, although the use of 3D EAM during VT ablations was not associated with a decrease in the procedure times, however, by decreasing the frame rate, we observed that there was a reduction in the total radiation dose exposure. As was eluded to previously, there is a learning curve associated with the use of 3D EAM, and as the physicians become comfortable with their use and reliance on the 3D EAM, the procedural times are expected to decrease across different types of catheter ablations.

AF and AT ablation procedures have shown a consistent decrease in the procedure time and radiation indices, but the difference was not statistically significant. We believe that the small number of these procedures performed in our laboratory explains the nonsignificant difference.

Although the 3D EAM has almost eliminated or limited the use of fluoroscopy, utilizing the strategies such as decreasing the frame rate when fluoroscopy is utilized not only during various catheter ablation but also during other electrophysiology procedures may help reduce the radiation exposure to the operators, the staff, and the patients as well. In our cohort, the fluoroscopy frame rate did not adversely affect in-hospital clinical outcomes of various ablation procedures.

**TABLE 3** In-hospital outcome of all the procedures

| | Pre group (171) | Post group (209) |
|---|---|---|
| Procedural success | | |
| VT (148) | 65 (97%) | 76 (94%) |
| VPC (44) | 15 (100%) | 27 (93%) |
| AFL (115) | 43 (100%) | 71 (99%) |
| AF (30) | 21 (95%) | 7 (87%) |
| AT (43) | 24 (100%) | 19 (100%) |
| Total (380) | 168 (98%) | 200 96% |
| Complications | | |
| Minor | 2 | 4 |
| AV Block | 0 | 1 |
| Tamponade | 0 | 0 |
| Access site complication | 0 | 0 |
| Stroke | 0 | 0 |
| Phrenic nerve palsy | 0 | 0 |

## 8 | CONCLUSION

The use of 3D EAM combined with decreasing the fluoroscopy frame rate resulted in a reduction of the total radiation exposure. Even in the era of zero-fluoroscopy, strategies such as decreasing the fluoroscopy to 3.8 fps or lower may allow for a decrease in exposure to the ionizing radiations without compromising the in-hospital patient outcomes.

## 9 | LIMITATIONS

This study was a retrospective analysis of the data collected from a single center with all the drawbacks of a retrospective analysis.

Supraventricular tachycardia ablations are the most common ablation procedures performed in our laboratory, but most of them are performed without using 3D EAM systems.

Most of the data of radiation exposure vis-a-viz 3D EAM systems are those of AF ablation. In this study, AF ablation procedures constituted only 8% of the procedures.

We estimated the ED from DAP, as suggested by EHRA practical guide, but the most accurate method for the estimation of ED is with Monte Carlo simulations.[2]

The radiation dose delivered is also dependent on the body mass index of the patients. Unfortunately, that data were not available.

**TABLE 4** Radiation exposure data reported in different studies (adapted and modified from (4)) DRM: dose reduction maneuvers

| Study | Type of study | Type of procedure/ Number of patients | Fluoroscopy Time (min) | DAP (cGycm$^2$) | Effective Dose (mSv) |
|---|---|---|---|---|---|
| Smith IR et al (16) | Retrospective | VT 97 | 17.4 (9.7-26.4) | 2080 (1150-3150) | 2.9 (1.6-4.4) |
| Heidbuchel H et al (2) | EHRA practical guide | VT | - | - | 12.5 (3-≥45) |
| Casella M et al (4) | Retrospective | VT 453<br>VPC 450 | 36(24-49)<br>13(7-22) | 13 849(5606-23 429)<br>2609(925-6178) | 28.4(11.7-47.7)<br>6.2(2.1-13.5) |
| Razminia M et al (zero fluoro)(9) | Retrospective | VT 14<br>VPC 30 | 0<br>0 | -<br>- | -<br>- |
| Smith IR et al(16) | Retrospective | AFL 498<br>AT 124 | 16.8 (9.5-30.5)<br>14.9 (7.7-28) | 1890 (1130-3530)<br>1770 (900-3510) | 2.6 (1.5-4.9)<br>2.4 (1.2-4.9) |
| Casella (4) | Retrospective | AF 2416<br>AFL/AT 468 | 23 (15-35)<br>14 (7-24) | 7373 (3735-13 628)<br>3231 (1381-6958) | 16.0 (8.2-28.8)<br>7.3 (3.1-14.7) |
| Rogers DP et al (11) | Observational | Pre DRM (AF 79, VT3)<br>Post DRM (AF 263, VT 14) | | 6330 ± 1850<br>3280 ± 3170 | 7.99<br>2.83 |
| Heidbuchel H et al (2) | EHRA practical guide | AF<br>AT- AVNRT-AVRT | - | - | 16.6(6.6-59.6)<br>4.4 (1.6-25) |
| Razminia M et al (zero fluoro)(9) | Retrospective | AF 186<br>AFL 188<br>AT 111 | 0.3<br>0<br>0 | -<br>-<br>- | -<br>-<br>- |
| Lee JH et al (13) | Retrospective | AF Pre DRM 57<br>AF Post DRM 76 | 24.4 (17.5-34.9)<br>15.1 (10.7-20.1) | 599.9 (371.4-1337.5)<br>392.0 (289.7-591.4) | 1.1 (0.7-2.5)<br>0.7 (0.6-1.1) |

Individual radiation exposure of the operators and the other staff was not available.

We have not analyzed operator-wise procedural data regarding the radiation exposure indices because there are always two operators, along with the EP fellows, in the laboratory performing the procedures, and to individualize the exposure indices is not possible.

We have reported only in-hospital procedural outcomes. No long-term follow-up data regarding outcomes were available.

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## CONFLICT OF INTEREST

None.

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