Patients’ Radiation Exposure during Various Types of Cardiac Arrhythmias Ablation

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ABSTRACT

Background: Cardiac Radiofrequency (RF) ablation is used for treating some types of heart rhythm problems. The number of RF ablation procedures is increasing rapidly due to lower complication risks than surgery and high success rates. Due to higher patient exposure to X-ray radiation in different cardiac ablation procedures, public concerns are increasing regarding the detrimental effects of ionizing radiation, including skin injury, genetic effects, and malignancy.

Objectives: This study aimed to determine patient absorption doses during Electrophysiological Study (EPS) and RF ablation of different cardiac arrhythmias in an electrophysiology laboratory unit with a flat panel detector.

Patients and Methods: This cross-sectional study was performed on 223 patients who underwent cardiac EPS and RF ablation. All procedures were executed on a single panel angiography unit with floor mounted C-arm. Dose Area Product (DAP), Entrance Skin Dose (ESD), and Fluoroscopy Time (FT) were recorded in all different procedures. Also, Total FT (TFT), total DAP, and total ESD were analyzed in the 223 procedures separately. Pearson’s correlation test was used to estimate the relationships between FT and DAP, FT and ESD, and ESD and DAP.

Results: In this study, 56.1% of the patients were female. The mean age of male and female patients was 43.9 and 47.7 years, respectively. Medians of TFT, total ESD, and total DAP were 7.4 min, 165 mGy, and 19.2 Gycm2, respectively. Total ESD was strongly correlated to DAP (r = 0.945, P < 0.001). Significant correlations were also observed between FT and DAP (r = 0.843, P < 0.001) and between FT and ESD (r = 0.747, P < 0.001). AF ablation procedures had the highest medians of DAP, ESD, and FT values during all types of cardiac arrhythmias.

Conclusions: For prevention of deterministic and stochastic effects of radiation exposure, such as skin damage and cancer, operators should attempt to reduce patients’ radiation exposure as low as reasonably achievable. In the current study, none of the patients’ ESDs exceeded the threshold dose. The maximum ESD and DAP values were attributed to AF ablation procedures. Significant correlations between DAP and FT as well as between ESD and FT and the strong correlation between DAP and ESD showed that ESD could be reduced by reducing FT and DAP.

1. Background

Cardiac fluoroscopy is used for diagnostic purposes, catheter positioning, interatrial septal puncture, focal and linear ablation, pericardiocentesis, and mapping of arrhythmias. Radiofrequency (RF) ablation is a well-proven technique used for treating some types of heart rhythm problems, such as Ativoventricular Nodal Reentrant Tachycardia (AVNRT), Atrial Flutter (AFL), Atrial Fibrillation (AF), Atrial Tachycardia (AT), Ventricular Tachyarrhythmia (VT), Premature Atrial Contractions (PAC), Premature
Ventricular Contractions (PVC), and Wolff-Parkinson-White Syndrome (WPW). The number of RF ablation procedures is increasing rapidly due to lower complication risks than surgery and high success rates. These procedures have replaced pharmacological therapy and are performed under fluoroscopy guidance (1-6). RF ablation procedures require more prolonged Fluoroscopy Time (FT) compared to conventional angiography. Some ablation procedures need substrate modification that increases the procedure and fluoroscopy time substantially, which can increase the potential risk for both patients and operators. Due to higher patient exposure to X-ray radiation in different cardiac ablations, global concerns are increasing regarding the biological effects of ionizing radiation, including skin injury, genetic effects, and malignancy, especially for young patients (7-10). These biological effects are divided into deterministic and stochastic categories. Skin injury is a deterministic effect of radiation and the severity of the effect increases with increasing the radiation dose exceeding the threshold. According to Food and Drug Administration (FDA), cardiac catheter ablation has the potential to induce serious skin damage (11). Also, multiple diagnostic procedures can occasionally lead to enhancement of cumulative dose and induce skin injury. In addition to deterministic effects, ionizing radiation has stochastic effects. Gene mutation and genomic instability, chromosomal abbreviation, cellular transformation, cell death, and carcinogenesis are some stochastic effects of ionizing radiation in mammalian cells. Carcinogenesis is a somatic and stochastic effect of radiation exposure and is indistinguishable from those occurring due to other reasons. Since DNA is a critical target in mammalian cells, ionizing radiation can induce various types of DNA lesions, such as single-strand breaks and double-strand breaks. Although very low doses of radiation can induce double-strand breaks, they can be repaired by repairing mechanism very effectively. In fact, all primary DNA lesions are exposed to cellular repair processes, but badly-repaired or unrepaired ones may cause chromosomal aberrations and induce cancer and malignancy (12). Thus, for prevention of deterministic and stochastic effects of radiation exposure, such as skin damage and cancer, it is necessary to reduce radiation exposures as low as reasonably achievable. Modern angiography systems have been equipped with transmission ionization chamber to measure the Dose Area Product (DAP). Total DAP and total Entrance Skin Dose (ESD) are good quantities for estimating the DAP, ESD, and FT were recorded in different procedures, including EPS, AVNRT, Atrio Ventricular Reentrant Tachycardia (AVRT), WPW, PVC, AT, VT, AF, Right Postero septal (Rt-PS) accessory pathway, Left Postero septal (Lt-PS) accessory pathway, Left Septal Ventricular Tachycardia (LSVT), Left Ventricular Outflow Tract (LVOT), Right Ventricular Outflow Tract (RVOT), and left lateral and and Rt-anterior-free wall accessory pathway ablation. Also, Total FT (TFT), total DAP, and total ESD were analyzed in the 223 procedures separately. Moreover, the correlations between FT and ESD, FT and DAP, and DAP and ESD were analyzed.

3.1. Statistical Analysis
All statistical analyses were performed using IBM statistics 22 (SPSS Inc., Chicago, Illinois). Descriptive statistics with median, 1st quartile, and 3rd quartile were used to summarize the patients’ radiation doses. Besides, Pearson’s correlation test was used to estimate the relationships between FT and DAP, FT and ESD, and ESD and DAP. P < 0.05 was considered to be statistically significant.

4. Results
In this study, 56.1% of the patients were female. The mean age of male and female patients was 43.9 and 47.7 years, respectively. The details of radiation exposure, such as DAP, FT, and ESD, for EPS and ablation of each type of arrhythmias have been presented in Table 1. Additionally, TFT, total ESD, and total DAP values in the 223 patients with various types of cardiac arrhythmias have been depicted in Table 2. It should be noted that due to non-normal distribution of the data, all values have been represented as median, 1st quartile, and 3rd quartile. The correlations between ESD and FT, DAP and FT, and ESD and DAP have been shown in Figures 1, 2, and 3, respectively. Accordingly, total ESD was strongly correlated to DAP (r = 0.945, P < 0.001). Significant correlations were also observed between FT and DAP (r = 0.843, P < 0.001) as well as between FT and ESD (r = 0.747, P < 0.001). AF ablation procedures had the highest medians of DAP, ESD, and FT values.

5. Discussion
The values reported in the present study were considerably different from those of the present study.
Several researchers have investigated radiation exposure parameters during cardiac RF ablation procedures. Tsapaki et al. (14) collected data from three digital angiography units, two of which being with image intensifier and one with a flat panel detector. They investigated 134 patients with different electrophysiological studies as well as 203 cases of Percutaneous Transluminal Coronary Angioplasty (PTCA). They used slow radiotherapy films for measuring Kerma Area Product (KAP), total KAP, maximum ESD, and FT in these procedures. They observed the highest KAP value in RF ablation procedures in comparison to interventional cardiac procedures and showed that the medians of FT and KAP for AF ablation were 45 min and 35 Gycm2, respectively. Similarly, Kidouchi et al. (8) investigated 99 patients, including 75 males and 24 females. Catheter ablations for cardiac arrhythmias were performed with six different types of angiographic units in three institutions. The angiographic systems were monoplane and biplane with image intensifier and digital flat panel detector. Differences of cardiac arrhythmia were studied. They put special jackets on patients’ backs, which had 100 radiosensitive indicators arranged in 10 columns and 10 rows 5 cm apart. After the procedure, they calculated ESD. FT, maximum ESD, and DAP of each intervention were evaluated as well. Based on the results, only three patients exceeded the 2 Gy threshold dose, but no sign of skin damage was seen after the procedures. Additionally, TFT was about 30 min in the non-AF group in comparison to those reported in most previous studies. Medians of TFT, total ESD, and total DAP were 7.4 min, 165 mGy, and 19.2 Gycm2, respectively. The maximum ESD and DAP values were attributed to AF ablation procedures.

In this study, all ablation procedures were carried out by two experienced electrophysiologists at the same time as the operator and co-operator with a flat panel angiography unit. Therefore, variations in ranges of FT, ESD, and DAP values were attributed to AF ablation procedures. They used slow radiotherapy films for measuring Kerma Area Product (KAP), total KAP, maximum ESD, and FT in these procedures. They observed the highest KAP value in RF ablation procedures in comparison to interventional cardiac procedures and showed that the medians of FT and KAP for AF ablation were 45 min and 35 Gycm2, respectively. Similarly, Kidouchi et al. (8) investigated 99 patients, including 75 males and 24 females. Catheter ablations for cardiac arrhythmias were performed with six different types of angiographic units in three institutions. The angiographic systems were monoplane and biplane with image intensifier and digital flat panel detector. Different kinds of cardiac arrhythmia were studied. They put special jackets on patients’ backs, which had 100 radiosensitive indicators arranged in 10 columns and 10 rows 5 cm apart. After the procedure, they calculated ESD. FT, maximum ESD, and DAP of each intervention were evaluated as well. Based on the results, only three patients exceeded the 2 Gy threshold dose, but no sign of skin damage was seen after the procedures. Additionally, TFT was about 30 min in the non-AF group in comparison to those reported in most previous studies. Medians of TFT, total ESD, and total DAP were 7.4 min, 165 mGy, and 19.2 Gycm2, respectively. The maximum ESD and DAP values were attributed to AF ablation procedures. In this study, all ablation procedures were carried out by two experienced electrophysiologists at the same time as the operator and co-operator with a flat panel angiography unit. Therefore, variations in ranges of FT, ESD, and DAP values were attributed to AF ablation procedures.

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70 min in the AF group. Besides, the means of max ESD and DAP were respectively 0.57 ± 0.51 Gy and 71.2 ± 73.7 Gycm² in the AF group. Furthermore, the results revealed strong correlations between DAP and max ESD in all three angiographic units (r = 0.937, r = 0.927, and r = 0.905, respectively).

Chida et al. (17) also determined ESD and DAP values in RF ablation procedures. The results showed that the mean ± SD of DAP, ESD, and TFT was 109.7 ± 74.7 Gycm², 635 ± 551.6 mGy, and 120.8 ± 62.6 min, respectively. In addition, a strong correlation was found between ESD and DAP (r = 0.942, P < 0.001). A significant correlation was also observed between ESD and TFT (r = 0.801, P < 0.001).

Overall, the radiation exposure parameters were higher in all above-mentioned researches compared to the present study. On the other hand, the findings of the current study were higher than those obtained by Reents et al. They indicated a significant reduction in FT (10.57 ± 7.93 vs. 18.52 ± 11.24 min) and DAP (611 vs. 1650 cGycm²) in patients who underwent VT ablation. This reduction might have resulted from utilization of 3D mapping system, which was not used in our investigation (5). 3D mapping system, a non-fluoroscopic one, requires special catheters that are more expensive than conventional ones. Although these systems are helpful for reduction of FT, they are not cost-effective for ablation of simple arrhythmias, especially in developing countries, and should be used in complex arrhythmias, such as VT and complex AF (18).

Reduction of patients’ radiation exposure is a good approach to reduce the biological effects of ionizing radiation. These biological effects are divided into stochastic and deterministic categories. The “Linear Non Threshold” (LNT) model is accepted for stochastic effects, such as genetic effects and cancer. In this model, with increase in the radiation dose, the risk of cancer increases linearly. Since DNA is a critical target in mammalian cells, ionizing radiation can induce various types of DNA lesions, such as single-strand breaks and double-strand breaks. If primary DNA lesions are badly repaired or unrepaired, they may cause chromosomal aberrations and induce cancer and malignancy (12). For deterministic effects, such as cataract and skin injury, radiation can induce cell and tissue injury. These main effects do not occur below the threshold of radiation dose and the severity increases with the dose (11, 13, 19, 20). According to the International Commission on Radiological Protection 85 (ICRP 85), patients’ skin reactions will occur by different amounts of X-ray radiation. For instance, early transient erythema occurs at the threshold dose of 2 Gy, temporary epilation at 3 Gy, and major erythema at 4 Gy (21). Moreover, since the number of cardiac ablation procedures has increased rapidly, public concerns are rising regarding biological effects and enhancement of genetic significant dose. Genetic significant dose is defined as individual gonad
doses received by examined patients, which has the same genetic effect on the upcoming offspring. Therefore, operators should attempt to reduce patient radiation exposure as low as possible. In the current study, DAP values were well less than the European RF ablation reference level; i.e., 46 Gycm² (21, 22). Overall, using high technology angiography and 3D mapping systems would reduce patients’ absorbed doses without inducing acute skin injuries.

5.1. Conclusion
In the current study, none of the patients’ ESDs exceeded the threshold dose. The max ESD and DAP values were attributed to AF ablation procedures. The results revealed significant correlations between DAP and FT as well as between ESD and FT. A strong correlation was also observed between DAP and ESD, which implies that ESD can be reduced by reducing FT and DAP.

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Authors’ Contribution
Somayeh Delavarifar: study concept and design, drafting of the manuscript; Mohammad Hossein Nikoo, Mohammad Vahid Jorat: Providing the cases, do the clinical operation, scientific writing of the manuscript, study supervision; Amir Savardashka: data gathering; Mehrab Sayadi: statistical analysis and designing the manuscript.

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