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ORIGINAL ARTICLE

Pulmonary Vein Isolation for Atrial Fibrillation Can Be Achieved with Low Radiation Exposure

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Background Atrial fibrillation is common and management by pharmacotherapy is limited by modest efficacy and significant toxicities. Pulmonary vein isolation (PVI) is a safe and effective alternative in select patients with atrial fibrillation. However, prolonged procedure time raises concerns of health risks from radiation exposure. This study aims to determine the significance of radiation exposure from PVI.

Methods In this study, we retrospectively reviewed patient demographics, fluoroscopy time, entrance skin dose and dose area product in 80 cases of PVI, radiofrequency ablation for atrial flutter and diagnostic coronary angiogram performed in our institution.

Results Compared to other procedures, patients who underwent PVI were younger (age, mean ± standard error of mean, 59.4 ± 1.1 years old, $p < 0.0001$) and were more likely to be male (82%, $p < 0.001$). Body mass index was similar between the three groups. The median (and interquartile range) fluoroscopy time was similar between PVI (20.8 and 13.1–30.7 mins) and flutter ablation (17.6 and 11.1–26.1 mins) but longer than diagnostic angiography (4.2 and 2.3–6.7 mins, $p < 0.0001$). Entrance skin dose was similar between PVI and flutter ablation groups but significantly higher in the diagnostic angiography group, with median and IQR for PVI vs. flutter ablation vs. diagnostic angiography, 100.4 (52.8–179.9) vs. 73.2 (37.0–142.1) vs. 393.5 (276.1–555.6) mGy ($p < 0.0001$). Dose area product in PVI (1831.2 and 887.7–3460.8 cGycm^2) was higher than flutter ablation (1077.8 and 452.9–2410.2 cGycm^2, $p < 0.05$) but lower than the diagnostic angiography group (3446.8 and 2341.9–5283.1 cGycm^2, $p < 0.0001$). The fluoroscopy time and entrance skin dose for PVI decreased over time, likely due to increased operator experience.

Conclusions Despite prolonged procedure time, radiation exposure from PVI was comparable to, or lower than, other fluoroscopy-guided cardiac procedures.

Keywords Atrial fibrillation • Pulmonary vein isolation • Catheter ablation • Radiation

Abbreviations: ANOVA, Analysis of Variance; BMI, Body mass index; IQR, Interquartile range; cGycm^2, Centi-Gray square centimetre; Gy, Gray; mGy, Milli-Gray; mSv, Milli-Sivert; NS, Not significant; PVI, Pulmonary vein isolation; SEM, Standard error of mean; Sv, Sivert; vs., versus

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Introduction

Atrial fibrillation is the most common sustained cardiac arrhythmia encountered in clinical practice and carries significant morbidity and mortality [1]. In patients with symptomatic atrial fibrillation, pharmacotherapy, in conjunction with direct-current cardioversion, has been the mainstay of treatment for restoration and maintenance of sinus rhythm. However, anti-arrhythmic therapy is limited by modest efficacy and significant toxicities [2]. Since the late 1990s, recognition of ectopic discharges from pulmonary veins as an important trigger of atrial fibrillation has revolutionised our understanding and led to the development of catheter-based treatment for atrial fibrillation [3]. Electrical isolation of pulmonary vein (PVI) with radiofrequency energy has been shown to be a safe and effective alternative to pharmacotherapy, especially in patients with paroxysmal atrial fibrillation [4]. However, prolonged procedure time has raised concerns about excessive exposure to ionising radiation and consequent health risks [5].

Biological effects of ionising radiation are varied and can be categorised as either deterministic or stochastic. Deterministic effects are characterised by the presence of the effect ''threshold'', below which no effects are expected and above which the severity of the biological effects increases with higher radiation doses. Radiation dermatitis is an example of injury incurred when exposure to ionising radiation occurs above the ''threshold''. In contrast, for stochastic effects, which include risk of cancer and hereditary defects, there is no threshold. Rather, the probability of injury increases with higher radiation exposure. Different radiation dose measures are used to gauge these risks. Fluoroscopy time measures the duration that the x-ray is used. Entrance skin dose measures how much radiation is absorbed by the skin where the x-ray enters the body and is used to assess deterministic risks. On the other hand, dose area product is derived by multiplying the cross-section area of the x-ray beam by air kerma, which refers to the sum of kinetic energies of all charged particles released by ionising radiation per unit mass of air. Dose area product is indicative of stochastic risks. The most accepted measure of stochastic risk, however, is effective dose. Effective dose measures the whole-body health risk following radiation exposure, and takes into account the type of radiation used and the varied susceptibility of different tissues to radiation. Clinically, effective dose is not measured directly but can be derived from dose area product.

The aim of this study was to determine the radiation doses patients received during PVI and how this compares to other fluoroscopy-guided cardiac procedures. Secondly, we investigate the temporal trend of PVI radiation doses. In addition to quality assurance, this will provide information whether operator experience, a recognised determinant of procedure duration [6], also significantly impacts on the radiation doses from PVI.

Method

Study Populations

This is a single-centre, retrospective review. We examined 40 consecutive cases of PVI performed at the Royal North Shore Hospital, a large teaching hospital, between years 2010 and 2011, and another 40 consecutive cases performed in 2015. For comparison, 80 consecutive cases of radiofrequency ablation of atrial flutter and diagnostic coronary angiography performed in the same two time periods were audited. Patient demographics, height and weight were recorded and body-mass index (BMI) calculated. This study was approved by the Northern Sydney Local Health District Human Research Ethics Committee.

Radiation Dose Metrics

We retrieved three automatically-recorded radiation dose metrics including the fluoroscopy time, entrance skin dose and dose area product from the cardiac catheterisation laboratory x-ray unit (Toshiba Angiography Unit, Infinix CFi/SP, Model XTP8100G and XTP8100XG, Toshiba Medical Systems Corp., Otawara, Tochigi, Japan). Health risks of ionising radiation are often estimated using effective doses. To calculate the effective dose, we multiplied the dose area product by a conversion factor of 0.17 mSv/Gycm^2, as recommended by the United Nations Scientific Committee on the Effects of Atomic Radiation [7].

Pulmonary Vein Isolation

Prior to PVI, a computer tomography scanning or magnetic resonance angiography was obtained and used as the anatomical shell for CARTO®-3 (Biosense Webster Inc., Diamond Bar, CA, USA), a non-fluoroscopy electroanatomic mapping system. Transoesophageal echocardiography was performed at the beginning of the procedure to exclude left atrial thrombus. Intravenous heparin was used to maintain activated clotting time at around 300 secs. Catheter navigation was guided by the CARTO®-3 electromagnetic mapping system. In this system, electrophysiology catheters can be localised and visualised on the electroanatomic map through a combination of magnetic- and current-based technologies [8]. Left atrial access was obtained via a transseptal puncture or a patent foramen ovale. Pulmonary vein ostia were localised and wide area circumferential ablation was achieved using radiofrequency energy of 30–35 watts in the anterior aspect of the vein and 20–25 watts in the posterior left atrium. (Navistar® Thermocool® catheter, Biosense Webster, Inc., Diamond Bar, CA, USA). Oesophageal temperature was monitored during posterior left atrial ablation by positioning the temperature probe adjacent to the ablation sites. If significant or rapid rise in temperature was observed, power was reduced or interrupted. Pulmonary vein isolation was affirmed by the Lasso® catheter (Biosense Webster Inc., Diamond Bar, CA, USA) demonstrating entrance and exit block. After a 20–30 min waiting period to monitor for recovery of conduction, coronary sinus, left atrial appendage and

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