Comparison of operator radiation exposure during coronary sinus catheter placement via the femoral or jugular vein approach

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Aims
To evaluate and compare operator radiation exposure during the catheter placement in the coronary sinus via the femoral vein with a steerable catheter or the jugular vein with a fixed curve catheter.

Methods and results
A total of 156 patients undergoing electrophysiological study or radiofrequency catheter ablation were prospectively assigned in a random fashion to either the femoral vein access (FVA) with a steerable curve deca-polar catheter (n = 80) or the jugular vein access (JVA) with a fixed curve deca-polar catheter (n = 76). All the catheterization procedures were performed by the same operator who had extensive experience in both accesses. Operator radiation exposure was measured with an electronic radiation dosimeter attached to the breast pocket of the operator on the outside of the lead apron and estimates of the ambient dose equivalent were derived. The operator radiation exposure was reduced significantly by using the FVA compared with the JVA (1.8 ± 1.3 vs. 8.6 ± 6.5 mSv; P < 0.001). The fluoroscopy time (62.7 ± 45.8 vs. 61.9 ± 46.5 s; P = NS) and dose–area product (3.2 ± 2.3 vs. 3.1 ± 2.1 Gy cm²; P = NS) were not statistically different.

Conclusion
Operator radiation exposure can be significantly reduced by using the FVA approach with a steerable curve catheter compared with the JVA approach with a fixed curve catheter, without increasing the fluoroscopy time and dose–area product.

Keywords
Operator radiation exposure • Femoral vein • Steerable catheter • Fixed curve catheter

Introduction
A mapping catheter positioned in the coronary sinus (CS) serves as an important reference during diagnostic electrophysiology and ablative procedures. The CS catheter provides crucial anatomical landmarks and electrical conduction sequences in the heart. A conventional approach for CS catheter placement is to insert a fixed curve multi-polar catheter through the jugular vein and the supra vena cava (SVC). The jugular vein access (JVA), although successful most of the time, has several disadvantages. It may pose the risk of pneumothorax, haemothorax, and injury of a non-compressible artery. Additionally, the operator must be very close to the radiation source; therefore, the operator radiation exposure is rather high. This poses a potential risk of long-term undesirable radiation hazards for the operator. It is feasible to place a CS catheter through the femoral vein and the inferior vena cava (IVC) using a steerable catheter.³ The purpose of this study is to evaluate and compare the operator radiation exposure during CS catheterization via the femoral vein access (FVA) or JVA.

Methods
Study design
All patients scheduled for an electrophysiology study (EPS) or a radiofrequency catheter ablation (RFCA) in our hospital were enrolled in the study. After informed consent was obtained, the CS catheterization procedure was performed either from a femoral or a JVA according to the random assignment by the same electrophysiologist who had extensive experience in CS catheterization via both FVA and JVA approaches.
Inclusion and exclusion criteria
After completion of the procedure, only those cases that fulfilled the following criteria were included for data analysis: (i) the CS catheter was placed successfully and (ii) the femoral or jugular vein could be accessed. Patients with left superior vena cava or the iliac vein occlusion and/or an unusual CS anatomy were excluded.

Coronary sinus catheter placement
All CS catheterizations were performed on the same digital single-plane cineangiography unit with an under-table X-ray tube. A 7’ magnification and pulse rate of 6-frames/s were selected to generally decrease the radiation exposure. All procedures were done with the same LAO 30° projection. A 6F steerable deca-polar catheter (Dynamic Deca, Bard Electrophysiology, Lowell, MA, USA) was placed into the CS via a femoral vein and the IVC for FVA approach (Figure 1). A 6F fixed curve deca-polar catheter (St Jude Medical, St Paul, MN, USA) was placed through the jugular vein and the SVC for JVA approach (Figure 2). Successful CS catheterization was defined by achievement of a stable catheter position with the distal electrode at the lateral margin of the heart and with the proximal electrode at the left side of the vertebral column (LAO 30°) within 20 min.

Radiation protection
The rubber lead shield was placed at the edge of operating table in all cases. A movable acrylic lead overhead radiation protection shield with a patient contour cut-out (0.5 mm lead equivalent; MAVIG, Munich, Germany) was pulled down to the patient’s abdomen only in cases of the FVA group. Standard protective measures, i.e. keeping a maximum distance from the X-ray tube and minimization of the field of view, were equally applied in all cases.

Radiation measurements
An electronic Geiger Muller dosimeter (R.A. Stephen 6000; Centronics, UK) was used to measure the operator radiation exposure. It was attached to the breast pocket on the outside of the lead apron. The distance from the centre of the upper surface of the X-ray source to the dosimeter was measured in every case. The dosimeter has an energy response ± 20% between 35 keV and 1.0 MeV and a dose range display from 0 to 9.999 mSv in steps of 1 mSv = 1000 μSv. The radiation dose was recorded at the beginning and the end of each CS catheterization. The patient radiation dose was expressed as dose–area product (Gy cm²) and the fluoroscopy time was recorded for each case.

Data analysis
All data are expressed as mean ± standard deviation. Comparison analysis between the two groups was performed with the student’s t-test. A P-value of <0.05 was considered statistically significant.

Results
Patient characteristics
One hundred and fifty-nine consecutive patients who underwent EPS and RFCA were enrolled. Three patients were excluded from the analysis due to anatomic abnormality. Two were from the FVA group and one was from the JVA group according to pre-procedure assignment. Two patients were excluded due to CS abnormality as the CS catheter placement was abandoned after failure to manoeuvre via both access approaches. Another patient was excluded due to iliac vein stenosis, as the CS catheter was finally placed via JVA. There was a total of 156 (98%) patients included for study analysis. There were 80 patients from the FVA group, of which atrial fibrillation (AF) was diagnosed in 32, atrial flutter (AFL) in 13, atrial ventricular re-entrant tachycardia (AVRT) in 11, atrial ventricular node re-entrant tachycardia (AVNRT) in 18, atrial tachycardia (AT) in 4, and ventricular
tachycardia (VT) in 2 patients. Of the 76 patients from the JVA group, AF was diagnosed in 12 patients, AFL in 14, AVRT in 9, AVNRT in 17, AT in 6, and VT in 2 patients. There was no statistical difference of the patient characteristics between the two groups (Table 1).

**Radiation data**

The results for the fluoroscopy time and radiation measurements are shown in Table 2. There was no statistical difference for the fluoroscopy time and dose–area product between the two access groups. The distance from the operator to the X-ray source was 77% greater in the JVA than the FVA ($P < 0.001$). The operator radiation exposure was 79% lower ($P < 0.001$) for the FVA than the JVA.

**Table 1 Baseline characteristics**

<table>
<thead>
<tr>
<th></th>
<th>Femoral vein access</th>
<th>Jugular vein access</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All patients, n</td>
<td>80</td>
<td>76</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Female, n (%)</td>
<td>38 (48)</td>
<td>35 (46)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Age (years)</td>
<td>47.9 ± 15.2</td>
<td>48.0 ± 13.7</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Body surface area (m²)</td>
<td>1.97 ± 0.14</td>
<td>1.99 ± 0.17</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Hypertension, n (%)</td>
<td>58 (73)</td>
<td>52 (68)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Diabetes, n (%)</td>
<td>10 (13)</td>
<td>9 (12)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>AVRT, n (%)</td>
<td>11 (14)</td>
<td>9 (12)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>AVNRT, n (%)</td>
<td>18 (23)</td>
<td>17 (22)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>AT, n (%)</td>
<td>4 (5)</td>
<td>6 (8)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>AF, n (%)</td>
<td>32 (40)</td>
<td>28 (37)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>AFL, n (%)</td>
<td>13 (15)</td>
<td>14 (18)</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>VT, n (%)</td>
<td>2 (3)</td>
<td>2 (3)</td>
<td>&gt;0.05</td>
</tr>
</tbody>
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AVRT, atrial ventricular re-entrant tachycardia; AVNRT, atrial ventricular nodal re-entrant tachycardia; AF, atrial fibrillation; VT, ventricular tachycardia; AFL, atrial flutter; AT, atrial tachycardia.

**Table 2 Fluoroscopy time and radiation measurements**

<table>
<thead>
<tr>
<th></th>
<th>Femoral</th>
<th>Jugular</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluoroscopy time (s)</td>
<td>62.7 ± 45.8</td>
<td>61.9 ± 46.5</td>
<td>NS</td>
</tr>
<tr>
<td>Dose–area product (Gy cm²)</td>
<td>3.2 ± 2.3</td>
<td>3.1 ± 2.1</td>
<td>NS</td>
</tr>
<tr>
<td>Operator radiation exposure ($μSv$)*</td>
<td>1.8 ± 1.3</td>
<td>8.6 ± 6.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>The distance between operator’s chest and X-ray source (cm)</td>
<td>105 ± 8</td>
<td>65 ± 5</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

NS: $P > 0.05$.

*Acceptable dose equivalent H*(10).

**Discussion**

The risk from radiation exposure arises from the use of ionizing radiation in the form of fluoroscopy X-rays during the diagnostic and ablation procedures. Exposure to doses of ionizing radiation poses a risk of detrimental effects for the procedure operators. The level of risk depends on the amount of the dose received by the individual. Detrimental effects, such as malignant diseases in those exposed and inherited defects in later generations, are stochastic effects for which it is assumed there is no threshold dose. Although the health risk of radiation exposure in EP labs is well known, occupational risks of radiation exposure for EP physicians over a lifetime are poorly defined. Younger operators may have much higher exposure than their predecessors due to an increasing procedure volume such as AF ablation and CRT implantation procedures. The long-term impact of chronic radiation exposure on operators should be brought to the forefront.

There are many factors that may affect operator radiation exposure. In this study, two access methodologies of the CS catheter were evaluated and compared. All catheterization procedures were performed in the same cineangiography unit and by the same operator. The results of this study demonstrated that the CS catheter placement via the FVA approach incurred a significantly lower radiation exposure to the operator compared with the JVA approach. This radiation exposure difference between the two approaches could be attributed to several factors. The significantly greater distance between the X-ray source to the dosimeter during the FVA contributes a disproportionately greater decease in radiation exposure, per the ‘inverse square law’. A lead shield may also more effectively protect the operator in the FVA approach. Mann et al. demonstrated in their study that a movable floor shield is an effective way to reduce radiation exposure substantially (Figure 3). In this study, a movable acrylic lead overhead radiation protection shield was also specifically used in the FVA group.

**Figure 3 The cartoon illustrates the comparison of the distances from the operator to the X-ray source via the jugular vein access and the femoral vein access approaches. It also shows the protective lead shield placed between the operator and the X-ray source provides additional protection to the operator by femoral vein access approach.**
The dosimeter placed at a height of 130 cm on the outside of the lead apron allowed for an estimate of the ambient dose equivalent $H \times (10)$. Such measurements are representative of neck and brain exposure. This has been raised as an important health issue for high-volume operators performing cardiac catheterization.\textsuperscript{6,7} From the study of Von Boetticher et al.,\textsuperscript{2,8} brain exposure can be expected to be $\sim 63\%$ of the ambient dose equivalent measured at a height of 130 cm. They also showed that the sum of the weight equivalent doses in all tissues and organs (effective dose $E$) can be derived from the ambient dose equivalent $H \times (10)$ by the equation $E = 0.029 H \times (10)$.

The fluoroscopy time and dose–area product during catheterization also determine the radiation exposure dose. In this study, all procedures were performed in the same cineangiography unit and under the same conditions. The body surface area and the fluoroscopy time were similar in the two accesses. Thus, every factor for patient radiation exposure was either the same or similar, as the dose–area products were not statistically different.

Data from this study demonstrate that the CS catheter placement via the FVA provides a significant protective benefit to the operators as they often have hundreds of procedures per year in busy EP centres. Although no systematic study has been conducted to evaluate the radiation exposure hazard to an EP practitioner, it is conceivable that reduction in cumulative radiation exposure will provide a significant safety benefit for these busy electrophysiologists who perform daily EPS and ablative procedures for years.

**Conclusion**

Operator-incurred radiation exposure can be significantly reduced by using the FVA with a steerable catheter when compared with the JVA with a fixed curve catheter during the CS catheter placement. It is conceivable that high-volume operators will receive more profound protective benefits from the FVA for CS catheterization. This is a very simple study and concept, but one that highlights the importance of always being aware of radiation dose, even for simple procedures. We need to collectively always make ongoing efforts to reduce radiation exposure both to patients and operators.

**Acknowledgement**

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**Conflict of interest:** D.S.H. is the Chief Scientist of Bard Electrophysiology.

**References**