Non-Fluoroscopic Catheter Visualization in AF Ablation: Experience from 375 Consecutive Procedures

Running title: Sommer et al.; Non-fluoroscopic catheter visualization in AF ablation

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Abstract:

Background - A technological platform (MediGuide™) has been recently introduced for non-fluoroscopic catheter tracking. No data on the safety of this technology is yet available in a large cohort of patients.

Methods and Results - Data from a prospective ablation registry were analyzed. All patients undergoing AF ablation procedures supported by non-fluoroscopic catheter visualization technology (NFCV) were included. Patient characteristics and procedural data and complications within the first 3 months were recorded. Between May 2012 and February 2014, a total of 375 patients underwent AF ablation using NFCV technology. The patients were predominantly male (68%), the majority was ablated for the first time (71%), LA was 43±6mm and LV function was normal (59±9%). The median ablation procedure time was 135min [113; 170], median fluoroscopy time 2.8 min [1.5; 4.4] and median radiation dose 789cGy·cm² [470; 1466]. Regression analysis demonstrated a significant decrease of fluoroscopy time, -dose and procedure time. To confirm the result and show overall changes, the initial 50 cases (group I) to the last 50 cases (group II) of the series were compared: fluoroscopy time decreased from 6.0min [4.1; 10.3] in group I to 1.1min [0.7; 1.5] in group II and radiation dose from 2363cGy·cm² [1413; 3475] to 490cGy·cm² [230; 654], respectively. 10 patients (2.7%) experienced complications: 5 cardiac tamponades (1.4%), 4 pseudoaneurysms (1.1%), and 1 stroke (0.3%).

Conclusions - AF ablation utilizing the NFCV technology is safe with a rate of complications of 2.7%. Procedure time (135min) is not prolonged. A dramatic reduction in fluoroscopy time and dose was achieved.

Key words: ablation, atrial fibrillation, fluoroscopy, radiation risk
Introduction

Catheter ablation has become a standard therapy in the treatment of atrial fibrillation (AF). While many different ablation strategies have been proposed and are currently applied, all ablation procedures share one commonality in their necessity for the use of fluoroscopy to visualize catheters. Heavy reliance on the use of live x-ray for ablation procedures was alleviated in the 1990’s with the advent of 3D electroanatomical mapping systems (EAMS) that helped to significantly reduce radiation time and dose. Integration of cardiac imaging using magnetic resonance imaging (MRI) and computed tomography (CT) was shown to further reduce fluoroscopy exposure during ablation procedure. More recently, a new technology for catheter visualization called the MediGuide™-(MG) technology (St. Jude Medical Inc. [SJM], St. Paul, MN, USA) has been introduced that can further facilitate reduction in radiation exposure. Details have been previously described. Briefly, single-coil sensors embedded in the catheter tip can be accurately localized by an electromagnetic field. Information about the 3D position and orientation of the tools is then transferred to the fluoroscopy system and is used to visualize the catheter tip in a virtual biplanar view projected on 2 pre-recorded cineloops. It has been previously shown that the application of the MG technology can lead to a significant reduction in fluoroscopy burden by using diagnostic catheters in atrial flutter and by using both diagnostic and ablation catheters in several supraventricular tachycardias (SVT) and atrial fibrillation (AF). There may be concerns that the application of the non-fluoroscopic catheter visualization (NFCV) technology may increase procedural risks in the absence of the catheter shaft visualization and catheter localization that is solely based on the location of the catheter tip. We evaluated any possible role of this new technology on procedure-related complications using a registry of all AF ablations performed at our institution using NFCV.
Methods

Patients

Between May 2012 and February 2014, all patients undergoing AF ablation supported by NFCV technology were included in a prospective registry. In addition to baseline characteristics of the patients (age, gender, co-morbidities, and AF history), procedural data such as procedure time, fluoroscopy time, fluoroscopy dose, ablation time, ablation concept and peri-procedural anticoagulation regimen were analyzed. All complications during the usual 48h in-hospital follow-up were recorded and analyzed. Long-term complications with late presentations were also followed at a 3-months clinical visit.

Technology description.

The NFCV system consists of three components: (I) a transmitter generating a 3D electromagnetic field; (II) a small single-coil sensor (<1 mm^3) assembled within an intracardiac device such as a conventional decapolar EP catheter (MediGuide-Enabled Livewire™, SJM) or an ablation catheter (Safire DUO™ Ablation Catheter, MediGuide-Enabled, and CoolPath DUO™, Ablation catheter, MediGuide-Enabled, SJM); and (III) a magnetic field reference sensor attached to the patient’s chest^2,3. The transmitter is integrated in the fluoroscopy detector of a conventional X-ray imaging system (Siemens Artis, Erlangen, Germany), aligning the fluoroscopy space with the 3D magnetic field. The sensor-equipped EP catheters can be either visualized on fluoroscopy or tracked non-fluoroscopically by the electromagnetic field. The first step in a typical NFCV ablation procedure is to record two short fluoroscopy loops (3s each) which are then used to non-fluoroscopically visualize the position and orientation of the catheter tips within the conventional X-Ray environment. It is important to note that the projection on the fluoroscopy loops does not require any active registration steps. Two compensation algorithms
are in place to account for primary and secondary organ movements. In particular, the system utilizes ECG leads to compensate for changes in the heart rate and the reference sensor allows compensation for the respiratory and patient movements. Therefore, patient movement or secondary organ motion due to changes in respiratory pattern or arrhythmias do not influence the stability of the catheter tip visualization.

**Ablation Procedure**

All procedures were performed by 6 different operators experienced with >300 conventional AF procedures. All cases started with a recording of cine-loops in RAO (15-20°) and LAO (45-55°). Since all patients were ablated in deep analgosedation, we used femoral arterial access to monitor the blood pressure invasively. Three venous access lines were created for two MG-enabled diagnostic catheters placed in the coronary sinus and the right ventricular apex, and a long steerable sheath (Agilis, SJM). In most cases, one transseptal access was used to achieve isolation of the pulmonary veins by the pace-and-ablate-technique and to subsequently confirm bidirectional block with a spiral diagnostic catheter (Optima, SJM or Reflexion, SJM). Catheter navigation in the left atrium was exclusively performed by manipulation of the steerable sheath.

The registry includes the first patient to be ablated upon commercial availability of MG-enabled ablation catheters (Safire Duo, MG-enabled or Coolpath Duo, MG-enabled, SJM) in May 2012. The workflow in the first 75 patients involved acquiring LA angiographies using an injection of 60ml of contrast dye into the pulmonary artery. Subsequently, we changed this approach to a direct injection of contrast dye via the long transseptal sheath into both superior pulmonary veins in order to obtain more direct anatomical information (*see figure 1*). An EAMS (EnSite Velocity, Version 4.0.1, SJM) in combination with a 3D reconstructed 256-slice CT was used in all patients to facilitate the procedure. A temperature probe was inserted (Sensitherm, SJM) to
ensure intraesophageal temperatures below 39°C. In case 41°C was exceeded, a gastroscopy was performed to rule out severe mucosal damage\textsuperscript{12}.

Pulmonary vein isolation (PVI) was utilized as the first cornerstone of the ablation strategy. Patients presenting with AF at the time of the procedure were cardioverted electrically in order to verify complete antral isolation by pacing maneuvers\textsuperscript{10}. After achieving PVI, a voltage map of the left atrium was created to determine the subsequent ablation strategy. No further ablations were performed regardless of left atrial diameter or the clinical presentation if normal endocardial voltage of >0.5mV was observed throughout the atrium and no stable left-sided atrial tachycardias were inducible. If low-voltage areas were identified, a substrate-modification strategy was employed using pace-and-ablate-techniques. Ablation of cavo-tricuspidal isthmus was only done if typical atrial flutter was induced by the pacing protocol or typical atrial flutter was documented on Holter ECG.

The anti-coagulation regimen included vitamin K antagonists (VKA) aiming at an INR of 2-3 on the day of the procedure, and direct oral anticoagulants (DOAC) that were paused for 24h before the procedure and re-initiated 6h after the ablation. The DOAC and non-therapeutic VKA-patients received 5,000 Units of heparin prior to the transseptal puncture with the overall dose in all patients after the transseptal being 100 Units/kg. The target for the activated clotting time (ACT) was 250-350s. After the procedure, heparin was antagonized in all patients with a maximum of 10,000 Units of protamine.

\textbf{Statistics}

For the primary outcome, data from the entire cohort were used in a linear regression analysis with the 95\% confidence interval shown. In this regression analysis, the number of procedures is an ordinal variable which was treated as continuous. Furthermore, a confirmatory comparison
was made between two subgroups of patients: group I (novice phase, patients 1-50) and group II (experienced phase, patients 325-375). Most continuous variables are presented as mean ± standard deviation (SD) and highly skewed variables as median with the first and third quartiles (25%; 75%). Categorical variables are expressed as number and percentage of patients. The differences between continuous values were assessed using an unpaired 2-tailed student’s t-test for normally distributed continuous variables, a Mann–Whitney test for skewed variables, and a χ² test for nominal variables. P-values > 0.05 were considered non-significant (n.s.). All analyses were performed using SPSS for Windows, Release 18.0 (SPSS Inc., Chicago, IL, USA).

Results

From May 2012 to February 2014, 375 AF ablation procedures were performed using NFCV technology. Complete follow-up data was available for 320/365 patients (88%). The included patients were predominantly male (68%) and 60 ± 10 years of age (see table 1). They presented with co-morbidities such as arterial hypertension (68%) and diabetes (9%). The LV function was decreased (<50%) in 45 patients (12%) and the LA diameter was significantly enlarged (>45mm) in 117 patients (31%). The dominant clinical manifestation of the arrhythmia was paroxysmal in 169 (45%); persistent in 149 (40%) and long-standing persistent in 57 (15%) patients. In 266 (71%) cases, the procedure was the patient’s first ablation. Of the remaining 109 (29%) patients, 67 (61%) had their previous ablation(s) at other hospitals, while 42 (39%) had been previously ablated at our institution. Oral anticoagulation was maintained using VKA in 154 (41%) such that the mean INR on the day of the intervention was 2.21 ± 0.34. In 221 (59%) patients, direct oral anticoagulants (DOAC) were used. 142/221 (64%) of the DOAC patients received dabigatran (usually 2 x 150mg/day), 75/221 (34%) received rivaroxaban (usually 1 x 20mg/day) and 4/221 (2%) apixaban (2 x 5mg/day). During the observational period, a
significant change was identified: in group I (the first 50 patients), only 27/50 (55%) were anti-coagulated with direct anticoagulants, whereas in group II (last 50 patients), 39/50 (77%) patients were on DOAC therapy.

Despite the fact that the majority of the patients presented with persistent or long-standing persistent AF (55%), additional modification of left atrial substrate was performed only in 87 (24%) patients. In 54/375 (15%) cases, ablation of the cavo-tricuspidal isthmus was added to the ablation concept because typical atrial flutter occurred or was inducible during the procedure. Complete PVI was achieved in 371 (99%) patients. Uncontrollable rise of the intraesophageal temperature despite energy reduction to <20W precluded complete PVI in the other 4 cases. The mean procedure time was 145 ± 45min with an ablation time of 42 ±19min (see table 2). The median fluoroscopy time of 2.8min (1.5; 4.4) and fluoroscopy dose of 789cGy*cm² (470; 1466) were observed in the entire population. A significant learning curve was observed in regression analysis: the regression coefficient for fluoroscopy time was -0.015 (-0.017; -0.011), for fluoroscopy dose -5.36 (-6.3; -4.4) and for procedure time -0.13 (-0.16, -0.08).

This was confirmed when comparing the first and last 50 patients. In particular, group I exhibited a fluoroscopy time of 6.0min (4.1; 10.3) which was significantly reduced to 1.1min (0.7; 1.5) (p<0.001) in group II (see figure 2a). A significant decline was also observed in fluoroscopy dose when comparing group I (2363cGy*cm² (1413; 3475) and group II (490cGy*cm² (230; 654) p<0.001) (see figure 2b). Lastly, procedure time was also significantly reduced from 169 ± 49min in group I to 128 ± 39min in group II (p<0.001) (see figure 2c). Efficacy was not the primary subject to our analysis, therefore no routine holter monitoring was performed in those patients. The rate of Re-Do procedures within a follow-up of 14 ± 7 months as an indirect marker for efficacy was 20/375 (5.3%) of the patients which is comparable to our conventional
procedures. 7-day-holter monitoring at 6 months was available for 80/375 (21%) patients only: recurrences of AF or AT > 30s were found in 19/80 (24%), 61/80 (76%) were in stable SR, in only 2/80 (2.5%) AAD treatment was delivered at 6 months after ablation.

Complications

In 375 patients ablated for AF using the MG technology, a total of 10 complications (2.7%) were observed. In 9 (90%) cases, the complication was diagnosed within the first 48h interval after the procedure. The remaining complication of femoral pseudoaneurysm was detected during a clinical visit after 3 months and was addressed with a conservative treatment at another hospital (manual compression with no residual flow). The most frequent complication was a pericardial effusion leading to tamponades that required pericardiocentesis in 5 patients (1.4%). The tamponades occurred in the case of 3 different operators, 3 patients on DOAC (170ml, 500ml, 700ml), and 2 patients with INRs of 2.3 and 2.35 on VKA (220ml, 300ml). We observed a total of 4 pseudo-aneurysms of the femoral artery in 2 patients on VKA (INRs of 2.8 and 0.9) in which case the patients received enoxaparin, and 2 patients on novel oral anticoagulants (NOAC) treatment. Three of these cases were successfully treated with manual doppler-guided compression, while 1 patient required a surgical intervention (VKA, INR 2.83). Lastly, one stroke occurred 30h after the procedure (NOAC) with a left-sided hemiparesis which was resolved with conservative treatment after 48h without sequelae (see table 3). We did not observe any phrenic nerve pulsy, pulmonary vein stenosis or atrio-esophageal fistula in these 375 patients.

Discussion

Several studies have recently shown that the application of the NFCV technology is associated with a significant reduction in fluoroscopy time and dose\textsuperscript{5,6,13}. This was also shown for AF
ablutions in a cohort 80 patients. The reported studies, however, included only a limited number of patients (10-80), leading to concerns regarding the safety profile of this technology having not been addressed. In this registry, 375 consecutive ablation procedures using the NFCV technology were analyzed. We were able to show that in a non-selected cohort of patients with only 45% paroxysmal AF and 29% repeat ablations, the effects of the new technology on fluoroscopy reduction could be confirmed. Overall, the median fluoroscopy time was 2.8min [1.5; 4.4] in all patients and only 1.1min [0.7; 1.5] in the last 50 patients of this series. Concerning overall radiation exposure for the patient CT scans have to be added to the dose delivered during the ablation.

More importantly, the complication rate was comparable to previously-published data. While we observed that 2.7% of the patients suffered from a complication, Dagres et al. reported a 3.9% complication rate in 1,000 AF ablations based on their single-center experience in 200914, Cappato et al. revealed complication rates of 4.5% and 3.6% in worldwide surveys15, 16. In these surveys, the rate for cardiac tamponade ranged from 0.9% to 1.3%. In our data, cardiac tamponade was the most frequent complication (1.3%) followed by complications related to venous access (fistula or arterial pseudoaneurysms) in 0.8%. The rate of tamponade is comparable to our daily experience from > 7000 AF ablations: 1-1.5%14. 4/5 tamponades occurred in the first 150 cases whereas only 1/5 was registered in the last 225 cases reflecting a learning curve especially when combining steerable sheath with NFCV technology. Only one complication related to vascular access did not occur within the first 48h following the procedure and as such, no late-onset pericardial effusion was observed as described previously by Cappato et al.17.

55% of patients received DOAC therapy in group I of our analysis (5/2012 to 11/2012).
This proportion increased to 77% in the last 50 patients considered in this study (11/2013-2/2014). The complications potentially related to the anticoagulation regimen were seen in both the VKA-group (n=4, 2,7% of all VKA patients) and the DOAC group (n=6, 2.6% of all DOAC patients). In this relatively small cohort of patients, interruption of DOAC therapy 24h prior to the ablation procedure is likely as safe as non-discontinued VKA therapy. This is in line with results from a recent study reporting that uninterrupted DOAC therapy in AF ablation procedures is as safe as uninterrupted VKA-therapy18.

Despite the fact that the majority of patients presented with persistant or long-standing persistant AF, additional substrate-modification was performed only in 24% of the patients. According to our database from >3000 patients, approximately 10% of patients presenting with paroxysmal atrial fibrillation show abnormal findings in endocardial voltage mapping and only 40% of the persistant AF patients (unpublished data). The 24% of patients with additional lesions reflects that we report on a real-world-cohort. This approach is adapted to the findings of Verma et al. (2005) who showed that the presence of atrial scar revealed by endocardial voltage mapping is associated with impaired outcomes. The same findings were confirmed using MRI-based quantification of atrial scar by Mahnkopf et al.19. Additional ablation of the cavo-tricuspidal isthmus was performed in 15% of the patients only if typical flutter was inducible or documented in the ECG.

A learning curve of 5-10 procedures has been previously described in using the NFCV technology6,7. In AF ablation, in particular, approximately 50 patients were needed in the very initial experience before the workflow was fully optimized and the radiation exposure was reduced to reach the stable final level. Starting with optimal workflow using currently available software and catheters the learning curve should be in the range of 25 procedures.
Limitations

This study has the inherent limitations of a registry and prospective randomized studies are needed to confirm the findings. Since efficacy was not primarily addressed we did not perform holter monitoring in all patients, but only in a small subset of 80 patients. The observed improvements may be an overestimate for unexperienced operators since the participating interventionalists were highly experienced operators (>300 conventional AF ablations). During the study period, a total of approximately 3,000 PVIs were performed at our institution. While there may have been an underlying bias in the selection of patients undergoing NFCV ablation procedures, the baseline characteristics reflect a real-world scenario with predominantly persistent AF patients and structural heart disease in a large number of patients.

Conclusion

In this real-world cohort of patients, we were able to demonstrate that AF ablation procedures can be performed fast (mean procedure time of 150min) and safely (complication rate of 2.7%) using the new non-fluoroscopic catheter visualization system. Addition of the NFCV technology to a 3D mapping system results in a reduction of fluoroscopy time to 3.4min and a reduction of fluoroscopy dose to 1017cGy*cm². There is a learning curve of approximately 25 patients in using the system.

Conflict of Interest Disclosures: TG, SR received modest lecture fees by St. Jude Medical; PS, CP and GH received modest lecture fees and are advisory board members by St. Jude Medical.

References:

1. Caponi D, Corleto A, Scaglione M, Blandino A, Biasco L, Cristoforetti Y, Cerrato N, Toso E, Morello M, Gaita F. Ablation of atrial fibrillation: Does the addition of three-dimensional magnetic resonance imaging of the left atrium to electroanatomic mapping improve the clinical


**Table 1:** Patient baseline characteristics for the patients treated with the non-fluoroscopic catheter tracking system. Data is given for the overall population, group I (first 50 patients) and group II (last 50 patients).

<table>
<thead>
<tr>
<th></th>
<th>All 375</th>
<th>First 50</th>
<th>Last 50</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age [years]</strong></td>
<td>60 ± 10</td>
<td>60 ± 11</td>
<td>60 ± 8</td>
<td>n.s.</td>
</tr>
<tr>
<td><strong>Male Gender</strong></td>
<td>255 (68%)</td>
<td>35 (68%)</td>
<td>34 (68%)</td>
<td>n.s.</td>
</tr>
<tr>
<td><strong>Paroxysmal AF</strong></td>
<td>169 (45%)</td>
<td>24 (48%)</td>
<td>21 (42%)</td>
<td>n.s.</td>
</tr>
<tr>
<td><strong>Arterial hypertension</strong></td>
<td>250 (68%)</td>
<td>32 (65%)</td>
<td>38 (76%)</td>
<td>n.s.</td>
</tr>
<tr>
<td><strong>Diabetes</strong></td>
<td>33 (9%)</td>
<td>5 (10%)</td>
<td>4 (8%)</td>
<td>n.s.</td>
</tr>
<tr>
<td><strong>Structural heart disease</strong></td>
<td>78 (21%)</td>
<td>8 (16%)</td>
<td>13 (26%)</td>
<td>n.s.</td>
</tr>
<tr>
<td><strong>LV-EF [%]</strong></td>
<td>59 ± 9</td>
<td>60 ± 7</td>
<td>55 ± 10</td>
<td>n.s.</td>
</tr>
<tr>
<td><strong>LA diameter [mm]</strong></td>
<td>42 ± 6</td>
<td>42 ± 6</td>
<td>42 ± 7</td>
<td>n.s.</td>
</tr>
<tr>
<td><strong>Anticoagulation with DOAC</strong></td>
<td>221 (59%)</td>
<td>27 (55%)</td>
<td>39 (77%)</td>
<td>p&lt;0.05</td>
</tr>
</tbody>
</table>

p>0.05 is considered non-significant (n.s.)
Table 2: Procedural data for AF ablation procedures. Data is given for the overall population, group I (first 50 patients) and group II (last 50 patients).

<table>
<thead>
<tr>
<th></th>
<th>All 375</th>
<th>First 50</th>
<th>Last 50</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>First ablation procedure</td>
<td>266 (71%)</td>
<td>42 (84%)</td>
<td>34 (69%)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Procedure duration [min]</td>
<td>145 ± 45</td>
<td>169 ± 49</td>
<td>128 ± 39</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Fluoroscopy duration [min]*</td>
<td>2.8 (1.5, 4.4)</td>
<td>6.0 (4.1, 10.3)</td>
<td>1.1 (0.7, 1.5)</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Fluoroscopy dose [cGy<em>cm²]</em></td>
<td>789 (470, 1466)</td>
<td>2363 (1413, 3475)</td>
<td>490 (230, 654)</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>RF delivery [min]</td>
<td>42 ± 19</td>
<td>45 ± 21</td>
<td>39 ± 17</td>
<td>n.s.</td>
</tr>
<tr>
<td>RF pulses</td>
<td>22 ± 18</td>
<td>32 ± 22</td>
<td>18 ± 16</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>CTI ablation</td>
<td>54 (15%)</td>
<td>8 (16%)</td>
<td>6 (12%)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Linear lesions</td>
<td>87 (24%)</td>
<td>12 (24%)</td>
<td>14 (28%)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Complete PVI</td>
<td>371 (99%)</td>
<td>50 (100%)</td>
<td>49 (98%)</td>
<td>n.s.</td>
</tr>
<tr>
<td>Complications</td>
<td>10 (2.67%)</td>
<td>3 (6%)</td>
<td>1 (2%)</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

*Data given as median and interquartile ranges. P > 0.05 is considered non-significant (n.s.)
Table 3: Complications in 375 AF ablation procedures.

<table>
<thead>
<tr>
<th>Patient #</th>
<th>Type of complication</th>
<th>Age</th>
<th>Gender</th>
<th>Onset of complication</th>
<th>Anticoagulation</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>tamponade</td>
<td>46</td>
<td>Male</td>
<td>End of procedure</td>
<td>DOAC</td>
<td>Resolved after pericardiocentesis (500ml)</td>
</tr>
<tr>
<td>2</td>
<td>tamponade</td>
<td>53</td>
<td>Male</td>
<td>1h after procedure</td>
<td>VKA, INR 2.3</td>
<td>Resolved after pericardiocentesis (300ml)</td>
</tr>
<tr>
<td>3</td>
<td>pseudoaneurysm</td>
<td>35</td>
<td>Male</td>
<td>12h after procedure</td>
<td>DOAC</td>
<td>Resolved after manual compression</td>
</tr>
<tr>
<td>4</td>
<td>pseudoaneurysm</td>
<td>71</td>
<td>Female</td>
<td>8h after procedure</td>
<td>VKA, INR 2.84</td>
<td>Resolved after surgical intervention</td>
</tr>
<tr>
<td>5</td>
<td>tamponade</td>
<td>57</td>
<td>Female</td>
<td>2h after procedure</td>
<td>DOAC</td>
<td>Resolved after pericardiocentesis (170ml)</td>
</tr>
<tr>
<td>6</td>
<td>pseudoaneurysm</td>
<td>47</td>
<td>Male</td>
<td>3d after procedure</td>
<td>DOAC</td>
<td>Resolved after manual compression</td>
</tr>
<tr>
<td>7</td>
<td>tamponade</td>
<td>68</td>
<td>Female</td>
<td>End of procedure</td>
<td>DOAC</td>
<td>Resolved after pericardiocentesis (700ml)</td>
</tr>
<tr>
<td>8</td>
<td>pseudoaneurysm</td>
<td>58</td>
<td>Female</td>
<td>12h after procedure</td>
<td>VKA + enoxaparin, INR 0.9</td>
<td>Resolved after manual compression</td>
</tr>
<tr>
<td>9</td>
<td>tamponade</td>
<td>67</td>
<td>Female</td>
<td>End of procedure</td>
<td>VKA; INR 2.35</td>
<td>Resolved after pericardiocentesis (220ml)</td>
</tr>
<tr>
<td>10</td>
<td>stroke</td>
<td>62</td>
<td>Male</td>
<td>30h after procedure</td>
<td>DOAC</td>
<td>Resolved without sequelae</td>
</tr>
</tbody>
</table>
Figure Legends:

**Figure 1:** Ablation of atrial fibrillation using MediGuide. Left: RAO view (21°), middle: LAO view (44°). Markers were added for RSPV (green), RIPV (red); LSPV (blue) and LIPV (brown) using PV angiographies for LSPV (LAO) and RSPV (RAO). The CS catheter is visualized both by conventional fluoroscopy and MG (yellow tip). Additional markers show SVC- (pink ring) and IVC ostium (blue ring). The ablation catheter tip is MG visualized at the anterior ridge of LSPV. Right: visualization of the ablation catheter in the 3D mapping system. Intraesophageal temperature probe is used (green).

**Figure 2:** Fluoroscopy time (in min), fluoroscopy dose (in cGy*cm²) and procedure time (in min) for AF ablation procedures in 375 patients. The formula for linear regression analysis is given.
$y = -0.015x + 6.5$
\[ y = -5.5x + 2208 \]
y = -0.13x + 168
Non-Fluoroscopic Catheter Visualization in AF Ablation: Experience from 375 Consecutive Procedures
Philipp Sommer, Sascha Rolf, Christopher Piorkowski, Thomas Gaspar, Yan Huo, Carlos Piedra, Sergio Richter, Andreas Bollmann, Arash Arya and Gerhard Hindricks

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