Incidence and Long-Term Follow-Up of Silent Cerebral Lesions after Pulmonary Vein Isolation using a Remote Robotic Navigation System as Compared to Manual Ablation

Running title: Rillig et al.; Robotic AF Ablation and Silent cerebral lesion

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Abstract:

**Background** - The incidence of silent cerebral lesions (SCL) after atrial fibrillation (AF) ablation is highly variable depending on the technology used. Recently, an increased risk for SCL has been described for a novel, non-irrigated ablation tool using multielectrode phased radiofrequency (PVAC). The aim of this prospective study was to evaluate the incidence and long-term follow-up (FU) of SCL in patients (pts) undergoing robotically assisted pulmonary vein isolation (RA-PVI) as compared to manual PVI.

**Methods and Results** - Circumferential PVI using irrigated radiofrequency current was performed on 70 patients (41 pts with paroxysmal AF, 59%). Fifty patients underwent RA-PVI, and 20 pts underwent a manual approach. Cerebral MRI was performed the day before and the day after the ablation procedure; follow-up (FU)-MRI was performed on 9/12 (75%) pts after a FU-period of 21 months. SCLs were found in 12/70 (17%) pts in this study; the incidence of SCLs was similar in pts undergoing RA-PVI as compared to manually ablated pts (n=9, 18% vs. n=3, 15%, p-value = 1.0). In one patient undergoing manual PVI (1%), a SCL with asymptomatic subarachnoid haemorrhage was detected; the bleeding completely resolved within 1 month. Transient ischemic attack occurred in one (1%) patient two days after manual PVI. After a median FU-period of 21 months no residual SCLs were detected.

**Conclusions** - The incidence of SCL using the RNS was 18% in this study. Incidence and size of SCL appears to be similar following RA-PVI as compared to manual PVI. Repeat MRI showed no residual SCLs at long-term FU.

**Key words:** robotic navigation, pulmonary vein isolation, silent cerebral lesion, cerebral mri
Introduction
Pulmonary vein isolation (PVI) has been established as a treatment option for patients with symptomatic atrial fibrillation (AF) (1,2,3).

Recently, the feasibility of cerebral diffusion-weighted magnetic resonance imaging (MRI) to detect silent cerebral lesions (SCL) after PVI has been demonstrated (4,5). Currently discussions focus on the risk of SCL using new ablation tools, particularly after high incidence of SCL was recently reported using the non-irrigated duty-cycled ablation tool (PVAC) (6,7). The introduction of a new ablation tool such as the remote robotic navigation system (RNS, Sensei Hansen medical) raises the question of whether the incidence of SCL might be increased.

This prospective pilot study is the first to compare the incidence, size and long-term course of SCL in patients undergoing RNS-assisted PVI with a manual control group.

Methods
Patients
Overall, 70 consecutive patients (pts; female n=26, 37%) with paroxysmal (PAF; n=41, 59%) or persistent AF were included in this prospective pilot study. Fifty pts (PAF in 29 pts, 58%) underwent circumferential PVI (CPVI) using the RNS and were compared to a control group of 20 consecutive patients (PAF in 12 pts, 60%) undergoing manually performed ablation.

Exclusion criteria were age <18 years and >80 years, severe valve disease, acute coronary syndrome in the last 3 months, previous TIA or stroke, left atrial thrombus or spontaneous echo contrast in the left atrial appendage (LAA) or any contraindication to MRI. Left atrial thrombus or spontaneous echo contrast were excluded by transesophageal echocardiography the day before the ablation procedure.
Physical examination and careful neurological assessment were conducted on all patients before and after the ablation procedure.

Oral anticoagulation therapy was discontinued 5 days prior ablation and replaced by weight adapted low molecular weight heparin.

Enoxaparin in a weight-adapted dose (1mg/kg) twice daily was started immediately after sheath removal until INR >2 or equivalent. Phenprocoumon was started 48h after the ablation procedure.

The authors had full access to and take full responsibility for the integrity of the data. All authors have read and agreed to the manuscript as written.

**Pulmonary vein isolation**

Following written informed consent, all patients underwent ablation whilst under deep sedation using midazolam and fentanyl.

After having placed a coronary sinus catheter via the left subclavian vein, access for either two conventional transseptal sheaths (SL 0, length 63 cm, St Jude Medical, manual ablation group) or one conventional transseptal sheath and the Artisan™ sheath (AS, RNS group) was performed at the right femoral vein. Prior to the first transseptal puncture a heparin bolus of 3000 IE was administered intravenously. After the first transseptal puncture was performed, a conventional transseptal sheath (St. Jude medical SL0) was advanced into the left atrium. Thereafter, a second heparin bolus of 5000 IE was administered and after having removed the first transseptal sheath out of the LA with the guidewire left in the left superior pulmonary vein, either a second conventional transseptal sheath (manual approach) or the artisan sheath was introduced into the left atrium across the same puncture site as described previously.
In a final step the first transseptal sheath was advanced again into the left atrium over the guidewire. Activated clotting time (ACT) levels were measured every 30 minutes with a target ACT of 250-350 seconds according to current recommendations (9). Additional heparin boluses were administered to maintain the ACT levels above 250 seconds. The conventional transseptal sheaths were flushed with normal saline infusion with a flow-rate of 150 ml/h. The inner and outer sheaths of the artisan sheath were flushed with saline infusion (infusion of inner sheath warmed to 43°C to prevent bubble formation).

Selective angiography of the pulmonary veins was performed in 3 projections (posterior-anterior, left anterior oblique 30°, right anterior oblique 30°) to define the pulmonary vein ostia. Electroanatomical mapping was performed using the Ensite NavX system (St. Jude Medical, St. Paul, MN, USA). For mapping and radiofrequency current (RF) ablation, a 3.5 mm irrigated-tip ablation catheter (Cool path ns, St. Jude Medical, St. Paul, MN, USA) was used.

For CPVI a circumferential ablation line was deployed around the ipsilateral pulmonary vein (PV) ostia. Irrigated RF ablation was performed 0.5 to 1 cm proximal to the angiographically defined PV ostia. Power was limited in both patient groups to 20 watts at the posterior wall and 30 watts at the anterior aspect of the LA with an irrigation rate of 20 ml/min and a catheter tip temperature limit of 43°C. During RN-based ablation procedures, ablation was performed with a contact force of 10–40 g as assessed by IntelliSenseTM (Hansen Medical).

Endpoint of CPVI was complete isolation of all PVs defined as the absence of PV spikes registered on a decapolar Lasso catheter (Lasso, Biosense Webster, Diamond Bar, CA, USA) within the PVs. No additional ablation of CFAEs or left atrial isthmus (LAI) lines were routinely performed.
Cerebral MRI

MRI was performed before and after the ablation procedure using a 1.5 T MR imaging scanner (Signa Excite HD, GE Medical Systems, Milwaukee, WI, USA). In 9/12 (75%) pts with SCL, follow-up MRI was performed after a median follow-up period of 21 (19-22) months. The imaging protocol before the procedure consisted of a T2-weighted gradient echo sequence (GRE), a fluid attenuated inversion recovery sequence (FLAIR, inversion time (TI) 2200 ms), a T1-weighted spin echo sequence (SE), axial and sagittal T2-weighted fast spin echo sequences (FSE) and a diffusion-weighted single-shot echo-planar sequence (DWI, diffusion gradient b-values of 0, 500, and 1000 s/mm2). In addition, apparent diffusion coefficient (ADC) maps were calculated for every patient. After the ablation procedure the imaging protocol included the same DWI, FLAIR and T1w SE sequences as obtained before the intervention. Acute SCL on the postablation MRI was defined as a focal hyper-intense area in the diffusion-weighted images with corresponding hypo-intensity in the ADC map. All SCLs were analyzed for size and localization of the lesions. All MRIs were interpreted independently by two certified radiologists in a blinded manner.

Statistical analysis

Continuous data are expressed as mean ± standard deviation or median with first and third quartile (Q1-Q3). Categorical variables are summarized with absolute and relative frequencies.

The data were compared between the ablation groups and the patients with and without SCL. Continuous data were analyzed using the Student t-test or Wilcoxon-Mann Whitney test and categorical data were analysed using Chi-square analysis or Fisher’s exact test where appropriate. A p-value less than 0.05 was considered statistically significant.
All analyses were performed using the statistical software SAS software-version 9.2:

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Results

Baseline neurological assessment was normal in all pts.

CHADS$_2$ score was 0 in n=22 (31%), 1 in n= 39 (56%), 2 in n=9 (13%) patients.

There were no significant differences regarding the baseline-characteristics including the CHADS$_2$ score, left atrial diameter, left atrial appendage flow velocity or procedure related details of patients undergoing PVI using a manual approach vs. a robotically assisted approach (Table 1).

Ablation results

CPVI was successfully performed on all (n=70) patients. Additionally, LAI ablation was performed in 2 pts (4%) of the RA-group for perimital flutter.

Mean levels of activated clotting time (ACT) were 278.9 ± 35.3 seconds, minimum ACT levels 231.5 (203-250) seconds and maximum ACT levels 327 ± 39.7 seconds. There were no significant differences regarding the ACT levels between manually ablated patients compared to patients with robotically assisted PVI or patients with SCL compared to patients without SCL (Table 1 and Table 2).

Incidence of Silent Cerebral Ischemia

No recent SCL was found at baseline MRI; in 12/70 (17%) patients SCL was found the day after the ablation procedure (Figure 1).
CHADS₂ score was similar in patients with and without SCL (median 1 (0.5-1) vs median 1 (0-1), p=0.86).

There were no significant differences regarding the baseline-characteristics, left atrial diameter, left atrial appendage flow velocity, ACT levels or procedure related details in patients with or without SCL (Table 2).

In patients with SCL detected on cerebral MRI after the ablation procedure, electrical cardioversion was not performed more frequently than in patients without SCL (n=7 (58%) vs n=23 (40%), p=0.23). The number of electrical cardioversions during the ablation procedure also did not differ significantly (see Table 2).

The localization and distribution of the SCL is displayed in Table 3. The incidence of SCL was similar in the RN group compared to the manual ablation group (n=9, 18% vs n=3, 15%, p-value = 1.0). Multiple SCLs were seen in 2 pts of the RNS group. Neither the overall incidence nor the median size of the cerebral lesions differed significantly between the manual ablation group and the robotic ablation group (Table 1). One patient (1%) had a TIA 2 days following manual PVI. He presented with a left sided hemiparesis which completely recovered without significant sequelae within 24 hours. Interestingly, no SCL was detected one day after the ablation procedure.

In another patient undergoing manual-CPVI, SCL as well as asymptomatic intracerebral bleeding (subarachnoidal hemorrhage) of the right sided frontal and parietal region were detected by MRI the day after the ablation procedure (Figure 2). Repeat MRI within 2 days showed a reduction of the extent of the hemorrhage and no further signs of intracerebral bleeding were detected one month later in repeat MRI. The patient remained asymptomatic during follow up.
Follow-up MRI

Cerebral MRI was repeated in 9/12 (75%) patients after a median FU period of 21 (19-22) months (2 pts of the manual group and 7 pts of the robotic group); one patient died during the follow-up period and two patients refused to undergo further cerebral MRIs. No patient demonstrated residual SCLs or any glial scar formation upon follow-up MRI. In the robotic group, one patient who sustained a left sided parietal SCL after the procedure, presented with TIA and a transient paresis of the right arm seven months after the ablation procedure. Emergency cerebral MRI showed no new cerebral lesions and no remnant of the formerly described SCL.

Discussion

This is the first prospective study describing the incidence and long-term results of silent cerebral lesions after robotic AF ablation as compared to manual AF ablation.

The main findings of the present study are:

1. The incidence and size of silent cerebral lesions using RNS was similar compared to manual ablation.
2. No residual SCLs or any scar formation were seen in repeat MRI after a median FU-period of 21 (19-22) months.
3. Silent cerebral lesions did not predict subsequent procedural-related TIA

Incidence and risk factors for silent cerebral ischemia
Silent cerebral ischemia occurring during catheter ablation has been described previously and is
dependent on energy source, ablation site and the extent of the ablation (4, 6, 7, 10, 11).
The influence of different ablation tools on the incidence of SCL during PVI ranging from 5.6%
when using cryoenergy up to 38.9% when non-irrigated dury-cycled RF-ablation (PVAC) is
used, has been recently demonstrated (6,7,12).

There are several potential additional risk factors leading to an increased incidence of
silent cerebral lesions during PVI, including air embolism, micro-thrombembolism caused by
popping, charring at the catheter tip (13) or gaseous steam formation during RF-ablation
(14,15,16). Previous studies have identified electrical or pharmacological cardioversion as one of
the most important factors for SCL during PVI (5). In this study the incidence of SCL was 17%
but cardioversion or the number of cardioversions was not associated with an increased number
of SCL.

For electrical cardioversion it has been suggested that mechanical trauma or the restored
atrial contractility after AF termination may dislodge LA microthrombi, causing cerebral
embolism (5). Since gaseous steam formation during the ablation procedure may play a major
role in the formation of SCL during PVI, intraprocedural cardioversion might be of less
importance for the occurrence of SCL (15,16).

**Anticoagulation regimen and prevention of intracardiac thrombus formation**

Since the mechanism of SCL after PVI is not completely understood, the impact of ACT levels
on the incidence of SCL still remains debatable.

In general, lower ACT levels are associated with a higher risk for thrombembolic events
during left atrial catheter ablation (17,18) and therefore should be kept between 250-350 seconds
as recommended by the Venice chart (9). Further, ACT levels have been shown to be an
independent risk factor for the incidence of SCL during PVI (5). However, in the present study
no significant differences in ACT levels were seen between patients with or without SCL during
the procedure. Firstly, this might be, because all patients in this study had a narrow ACT range of
250-350 with most being around 300 seconds and secondly, a significant number of these SCLs
may not result from actual thrombus formation, but rather occur due to transient gas formation at
the time of ablation which is not affected by ACT levels (15).

In addition to SCL asymptomatic subarachnoid hemorrhage was seen in one patient of the
manual ablation group (patient one). This illustrates the difficulty in defining ACT levels which
are both safe and effective.

**Manually performed ablation versus RNS assisted ablation**

To the best of our knowledge, no data exist about the incidence of SCL following robotic AF
ablation as compared to a manual approach. Using robotic navigation may affect the risk for SCL
for the following reasons: a larger sheath (14F) is advanced into the left atrium (8), additional
flushing of the inner and outer robotic sheath is required (19, 20), the tip to tissue contact may be
enhanced using robotic navigation thereby potentially increasing the risk of charring, thrombus
formation or gaseous steam formation due to tissue overheating (13,15,16).

Tissue overheating causing increased steam formation might be one of the major reasons
why irrigated catheters still produce SCL as irrigation cools the catheter tip, but not the tissue.
However, in this study the potentially more powerful tool (i.e. RNS) with a supposed increased
tip to tissue contact did not result in a higher incidence of SCL.
Clinical implication and long-term course of SCL

The clinical relevance of SCL is still under debate. After PVI adverse neuropsychological changes in verbal memory have been found but were not directly associated with ischemic brain lesions on cerebral MRI (21). Data regarding the long-term course of SCL are sparse. Recently Deneke et al. could demonstrate that 94% of asymptomatic cerebral lesions observed acutely after AF ablation procedures healed without scarring at follow-up (22); only larger SCLs with more than 10mm in size showed the potential for glial scar formation. In the present study all SCLs were smaller than 10 mm in size (Table 3) and follow-up MRI which was performed on pts with SCL after a median FU-period of 21 (19-22) months revealed no residual SCLs or scar formation in any of the patients; these findings, which are in line with the findings reported by Deneke et al. (22) probably indicate that SCLs after PVI might be transient cellular membrane disruption/dysfunction due to largely gas emboli which then resolves.

Moreover, this study shows, that confirmation of SCL does not necessarily predict subsequent procedural-related TIA or stroke as one patient, without detected SCL after the procedure, experienced a TIA two days after the ablation.

Study limitations

This study is a prospective but non-randomized trial. However, there were no significant differences in the baseline characteristics between those patients undergoing RNS or having conventional ablation and the incidence of SCL. This study was intended to be a pilot study providing preliminary data on the incidence of SCL using RNS and thus contributing important information pertinent to the ongoing debate about SCLs and new ablation tools (6,7). The results
therefore have to be interpreted by taking note of the fact that the sample size was small, and therefore lacked statistical power to detect associations.

Since the exact mechanism of SCL still remains unclear, the use of intracardiac ultrasound may have helped to rule out thrombus formation at the transseptal sheath or to detect bubbles or gaseous steam formation (15,16,23). One of the major limitations is the fact that follow-up MRI was performed only in 75% of the patients with SCL after a median FU-period of 21 (19-22) months. Follow-up MRIs will be of major importance in future studies to clarify the time course and clinical relevance of SCL.

**Conclusion**

The incidence of SCL using the RNS was 18% in this study. In contrast to other novel ablation tools, incidence and size of SCL appears to be similar following RA-PVI as compared to manual-PVI. No residuals of SCL or glial scar formation were seen in repeat MRI after a median FU-period of 21 months.

**Conflict of Interest Disclosures:** None

**References:**


Table 1. Characteristics of patients with manually vs robotically assisted PVI

<table>
<thead>
<tr>
<th></th>
<th>Patients with manually performed ablation (n=20)</th>
<th>Patients with RNS assisted ablation (n=50)</th>
<th>p-value</th>
</tr>
</thead>
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<tr>
<td>Age (years)</td>
<td>66.5 (58-69.5)</td>
<td>60 (56-68)</td>
<td>0.14</td>
</tr>
<tr>
<td>Female, n (%)</td>
<td>5 (25%)</td>
<td>21 (42%)</td>
<td>0.18</td>
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<tr>
<td>Body mass index (kg/m²)</td>
<td>26.9 (25.3-28.9)</td>
<td>26.7 (24.9-29.7)</td>
<td>0.72</td>
</tr>
<tr>
<td>Hypertension, n (%)</td>
<td>15 (75)</td>
<td>31 (62)</td>
<td>0.30</td>
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<tr>
<td>Coronary artery disease, n (%)</td>
<td>0 (5)</td>
<td>(14)</td>
<td>0.29</td>
</tr>
<tr>
<td>Diabetes, n (%)</td>
<td>2 (10)</td>
<td>4 (8)</td>
<td>0.79</td>
</tr>
<tr>
<td>Hyperlipidemia, n (%)</td>
<td>5 (25)</td>
<td>16 (32)</td>
<td>0.56</td>
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<td>Creatinine level (mg/dl)</td>
<td>1.0 (0.85-1.1)</td>
<td>1.0 (0.9-1.1)</td>
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<tr>
<td>CHADS2 score</td>
<td>78 (66-99)</td>
<td>73 (61-87)</td>
<td>0.44</td>
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<tr>
<td>Left atrial diameter (mm)</td>
<td>47.5 (41-55)</td>
<td>47.5 (41-51)</td>
<td>0.58</td>
</tr>
<tr>
<td>Decreased LAA flow velocity*, n (%)</td>
<td>5 (25)</td>
<td>5 (10)</td>
<td>0.14</td>
</tr>
<tr>
<td>Cardioversion during procedure, n (%)</td>
<td>9 (45)</td>
<td>21 (42)</td>
<td>0.82</td>
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<tr>
<td>Number of cardioversions, n</td>
<td>0 (0-1)</td>
<td>0 (0-1)</td>
<td>0.67</td>
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<tr>
<td>Min ACT levels (sec)</td>
<td>226 (188.5-242.5)</td>
<td>233.5 (207-259)</td>
<td>0.25</td>
</tr>
<tr>
<td>Mean ACT levels (sec)</td>
<td>267.5 ± 40.5</td>
<td>285.5 ± 32.3</td>
<td>0.09</td>
</tr>
<tr>
<td>Max ACT levels (sec)</td>
<td>308.5 ± 42.3</td>
<td>331.5 ± 38.2</td>
<td>0.15</td>
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<tr>
<td>Incidence of silent cerebral ischemia, n (%)</td>
<td>3 (15)</td>
<td>9 (18)</td>
<td>1.0</td>
</tr>
<tr>
<td>Number of cerebral lesions, n</td>
<td>1 (1-1)</td>
<td>1 (1-1)</td>
<td>0.48</td>
</tr>
<tr>
<td>Mean size of silent cerebral ischemia (mm)</td>
<td>3 (3-4)</td>
<td>4 (3-4)</td>
<td>0.38</td>
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<tr>
<td>Max size of SCL (mm)</td>
<td>3 (3-4)</td>
<td>4 (3-4)</td>
<td>0.32</td>
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<tr>
<td>Left ventricular ejection fraction (%)</td>
<td>65 (60-65)</td>
<td>65 (62-65)</td>
<td>0.87</td>
</tr>
<tr>
<td>Paroxysmal atrial fibrillation, n (%)</td>
<td>12 (60)</td>
<td>29 (58)</td>
<td>0.88</td>
</tr>
<tr>
<td>Persistent atrial fibrillation, n (%)</td>
<td>8 (40)</td>
<td>21 (42)</td>
<td>0.88</td>
</tr>
<tr>
<td>Overall procedure time (min)</td>
<td>255 (225-325)</td>
<td>257.5 (210-290)</td>
<td>0.31</td>
</tr>
<tr>
<td>Fluoroscopy time (min)</td>
<td>17.1 (13.2-20.5)</td>
<td>16.4 (12.1-22.3)</td>
<td>0.67</td>
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<tr>
<td>Overall energy delivery (W)</td>
<td>93003 (77139-103121)</td>
<td>86953 (76024-111552)</td>
<td>0.82</td>
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<tr>
<td>Ablation of mitral isthmus line, n (%)</td>
<td>0 (0)</td>
<td>2 (4)</td>
<td>1.0</td>
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</table>

AF= atrial fibrillation, LAA= left atrial appendage; *Decreased LAA velocity defined as flow velocity <0.5 m/s

Continuous data are expressed as mean ± standard deviation or median (Q1-Q3).
Table 2. Characteristics of patients with and without silent cerebral ischemia detected by MRI

<table>
<thead>
<tr>
<th></th>
<th>Patients with silent cerebral ischemia (n=12)</th>
<th>Patients without silent cerebral ischemia (n=58)</th>
<th>p-value</th>
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<tr>
<td>Age (years)</td>
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<td>Female (n, %)</td>
<td>6 (50)</td>
<td>20 (66)</td>
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<td>Body mass index (kg/m²)</td>
<td>28.8 (26.4-30.3)</td>
<td>26.4 (24.7-28.7)</td>
<td>0.08</td>
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<td>Hypertension n (n%)</td>
<td>9 (75)</td>
<td>37 (64)</td>
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<tr>
<td>Coronary artery disease (n, %)</td>
<td>0 (0)</td>
<td>8 (14)</td>
<td>0.33</td>
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<tr>
<td>Diabetes n (n, %)</td>
<td>1 (8)</td>
<td>5 (9)</td>
<td>1.0</td>
</tr>
<tr>
<td>Hyperlipidemia (n, %)</td>
<td>1 (8)</td>
<td>20 (35)</td>
<td>0.09</td>
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<tr>
<td>Creatinine level (mg/dl)</td>
<td>0.95 (0.8-1.2)</td>
<td>1.0 (0.9-1.1)</td>
<td>0.79</td>
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<td>GFR (ml/min)</td>
<td>73.5 (59.5-79)</td>
<td>73.5 (65-89)</td>
<td>0.69</td>
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<tr>
<td>CHADS2 score</td>
<td>1 (0.5-1)</td>
<td>1 (0-1)</td>
<td>0.86</td>
</tr>
<tr>
<td>Left atrial diameter (mm)</td>
<td>48 (42.5-54.5)</td>
<td>47 (41-51)</td>
<td>0.60</td>
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<td>Decreased LAA flow velocity*, n (%)</td>
<td>0 (0)</td>
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<td>0.2</td>
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<tr>
<td>Cardioversion during procedure, n (%)</td>
<td>7 (58)</td>
<td>23 (40)</td>
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<td>Number of Cardioversions, n</td>
<td>0 (0-1)</td>
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<td>0.82</td>
</tr>
<tr>
<td>Min ACT level (sec)</td>
<td>238 (228-278)</td>
<td>227.5 (203-250)</td>
<td>0.16</td>
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<tr>
<td>Mean ACT levels (sec)</td>
<td>288.5 ± 31.4</td>
<td>276.5 ± 36</td>
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<td>Max ACT levels (sec)</td>
<td>337.5 ± 29</td>
<td>323 ± 41.6</td>
<td>0.49</td>
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<tr>
<td>Left ventricular ejection fraction (%)</td>
<td>65 (65-65)</td>
<td>65 (60-65)</td>
<td>0.14</td>
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<tr>
<td>Paroxysmal atrial fibrillation, n (%)</td>
<td>6 (50)</td>
<td>35 (60)</td>
<td>0.54</td>
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<tr>
<td>Persistent atrial fibrillation, n (%)</td>
<td>6 (50)</td>
<td>23 (40)</td>
<td>0.54</td>
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<td>Overall procedure time (min)</td>
<td>257.5 (210-302.5)</td>
<td>255 (220-300)</td>
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<td>Fluoroscopy time (min)</td>
<td>13.7 (11.2-30.1)</td>
<td>17.2 (12.6-22)</td>
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<td>Overall energy delivery (W)</td>
<td>89992 (78000-105467)</td>
<td>87025 (69956-117217)</td>
<td>0.91</td>
</tr>
<tr>
<td>Ablation of mitral isthmus line, n (%)</td>
<td>1 (8)</td>
<td>1 (2)</td>
<td>0.32</td>
</tr>
</tbody>
</table>

AF= atrial fibrillation, LAA= left atrial appendage; *Decreased LAA velocity defined as flow velocity <0.5 m/s ; GFR= glomerular filtration rate
Continuous data are expressed as mean ± standard deviation or median (Q1-Q3).
Table 3. SCL characteristics in patients with manually or robotically performed ablation

<table>
<thead>
<tr>
<th>Localization</th>
<th>Number of lesions (n=)</th>
<th>Max. Lesion size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ablation performed manually</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient 1</td>
<td>Left, central</td>
<td>1</td>
</tr>
<tr>
<td>Patient 2</td>
<td>Left, parietal</td>
<td>1</td>
</tr>
<tr>
<td>Patient 3</td>
<td>Right, central</td>
<td>1</td>
</tr>
<tr>
<td><strong>Ablation performed with RNS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient 1</td>
<td>Left, parietal</td>
<td>1</td>
</tr>
<tr>
<td>Patient 2</td>
<td>Left, parietal</td>
<td>1</td>
</tr>
<tr>
<td>Patient 3</td>
<td>Left, parietal</td>
<td>1</td>
</tr>
<tr>
<td>Patient 4</td>
<td>Right, frontal</td>
<td>1</td>
</tr>
<tr>
<td>Patient 5</td>
<td>Left, frontal, Left, central, Left parietooccipital, Right occipital</td>
<td>4</td>
</tr>
<tr>
<td>Patient 6</td>
<td>Left, frontal</td>
<td>1</td>
</tr>
<tr>
<td>Patient 7</td>
<td>Right, parietal</td>
<td>2</td>
</tr>
<tr>
<td>Patient 8</td>
<td>Right, periventricular</td>
<td>1</td>
</tr>
<tr>
<td>Patient 9</td>
<td>Left, frontal</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure Legends:

**Figure 1A:** shows SCLs of patients after manual performed PVI: From left to right: SCL located at a) left central, b) right parietal, c) left central. **B:** shows examples of SCLs of patients after robotically performed PVI: From left to right: SCL located at a) left frontal, b) right periventricular, c) left frontal

**Figure 2.** Silent cerebral lesion (left side) and subarachnoid hemorrhage (right side) after PVI in the same patient (patient one, manual group).
Incidence and Long-Term Follow-Up of Silent Cerebral Lesions after Pulmonary Vein Isolation using a Remote Robotic Navigation System as Compared to Manual Ablation

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