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ORIGINAL SCIENTIFIC PAPER

# Method, safety, and outcomes of persistent AF ablation without a circular mapping catheter: 3 years experience of a Belgian Tertiary Centre

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ABSTRACT
**Background:** We aimed to share our methods and experience of persistent AF ablation without a circular mapping catheter (CMC), thereby avoiding femoral venous and transseptal punctures, decreasing the cost of the procedure, and possibly reducing the duration of the procedure and fluoroscopy time.
**Methods:** We report our experience with 261 persistent AF ablations performed without a CMC over the past 3 years.
**Results:** The procedures were performed with no apparent loss of efficacy or safety. Freedom from recurrence was defined as a 1-year absence of AF/atrial flutter (AFL) episodes >30 s, beyond the 3-month blanking period. At 1 year, 72% of the patients were free from arrythmias.
**Conclusions:** Persistent AF ablation is feasible without a CMC, reducing the need for venous and transseptal punctures and the cost of the procedure. We suggest that prospective studies should aim to characterise the reduction in procedure and fluoroscopy times as a result of this technique.

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Atrial fibrillation ablation; persistent atrial fibrillation ablation; catheter ablation; circular mapping catheter; persistent AF

## Introduction

Catheter ablation (CA) of atrial fibrillation (AF), which is performed using radiofrequency (RF) or cryoablation, has become a cornerstone in the treatment of AF to prevent its recurrence. Although pulmonary vein isolation (PVI) alone has proven to be highly effective in sinus rhythm maintenance for paroxysmal AF [1,2], the optimal ablation strategy for persistent AF remains uncertain [3]. Although it is controversial, linear ablation of lesions in the left atrium, in addition to PVI, has been suggested to provide more efficiency in sinus rhythm maintenance [4,5].

Nevertheless, the cost of this procedure remains high due to the use of a navigation ablation catheter with a force sensor and a circular mapping catheter (CMC). Most centres still use such a CMC. To avoid trapping in patients with mitral mechanical valves, we started performing AF ablation without a CMC in 2016. The aim of this article is to share our experience in cases involving persistent AF ablation and show that the use of a CMC is not mandatory. This CMC-free approach can help avoid one femoral venous puncture and one transseptal puncture, reduce the manipulation of the catheter in the left atrium, and decrease the cost of the procedure. These benefits have been discussed in the context of paroxysmal AF in a previous report [6].

## Methods

In this registry study, we report the procedural characteristics, safety, success, and recurrence rates after 261 ablation procedures for persistent AF without the use of a CMC, which were performed at our Belgian tertiary centre between March 2016 and August 2019.

### *Ablation procedure*

CA was performed using a 3D electroanatomical mapping system (CARTO®; Biosense Webster Inc., Diamond Bar, CA, USA), a contact force-guided radiofrequency ablation catheter (ThermoCool® SmartTouch™ Catheter; Biosense Webster Inc.), and a duodecapolar catheter (Ismus® Catheter; Biosense Webster Inc.).

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Under general anaesthesia, after two right femoral vein punctures and the placement of the duodecapolar catheter in the coronary sinus, we performed a transseptal puncture under the guidance of transoesophageal echocardiography. The ablation catheter was introduced into the left atrium, and fluoroscopy was no longer used. We reconstructed a 3D shell of the anatomy of the left atrium using the ablation catheter. After the transseptal puncture, unfractionated heparin was administered with a target activated clotting time (ACT) of at least 300 s.

For persistent AF ablation, as recommended, we first performed PVI. We did not systematically perform linear ablation of left atrium lesions (LAL), but this decision was left to the operator's discretion. Some arguments in favour of such ablation lines are (non-exhaustively) strongly dilated left atrium (e.g. antero-posterior diameter >50 mm), long history of AF (especially episodes lasting for several months and/or long-standing persistent AF), and failure of multiple antiarrhythmic drugs (AADs).

If LAL was performed, we usually began with a roof and a mitral anterior line and often added an infero-posterior line to encircle the posterior wall. For all ablations, we used a point-by-point approach, while attempting to maintain an inter-lesion distance (ILD) <4 mm (diameter of the lesion tags of 4 mm, with contiguous tags) and apply a force time integral index (FTI) depending on the user's clinical judgement based on the changes in power, contact force, catheter stability, impedance drop, electrocardiogram (ECG) attenuation, location of the lesion, and lesion contiguity. The ablation index (AI) was not available in our centre before August 2019.

### Pulmonary vein isolation

Our method for performing PVI without a CMC has been previously described [6]. Briefly, we used a 'swing and fall' technique to determine the precise location of the ostia of the pulmonary veins, and then anatomically enclosed it by performing point-by-point ablation. For PVI, the upper limit of the FTI was 200 g·s on the posterior wall (25 W) and 300 g·s on the anterior wall (35 W).

### Mitral isthmus ablation

Linear mitral isthmus ablation was started on the ventricular side of the anterior mitral annulus (identified by the presence of both atrial and ventricular electrograms, with a small atrial deflection), after which the catheter was moved in a counter-clockwise rotation, joining the right superior pulmonary vein or the roof line. For the mitral isthmus, we delivered up to 40 Watts with an upper limit of an FTI of 400 g·s.

### Roof line

Roof line ablation was performed by positioning the catheter perpendicular to the roof of the atrium, then moving from the left superior pulmonary vein to the right, or vice-versa, to connect the superior margins of both superior pulmonary veins. We usually targeted an FTI of 300 g·s, although when we used a more posterior roof line (to obtain a better stability), we delivered a lower power, 25 or 30 W, and targeted an FTI of 200 g·s. Figure 1 shows 3D views of the anterior mitral line and roof line.

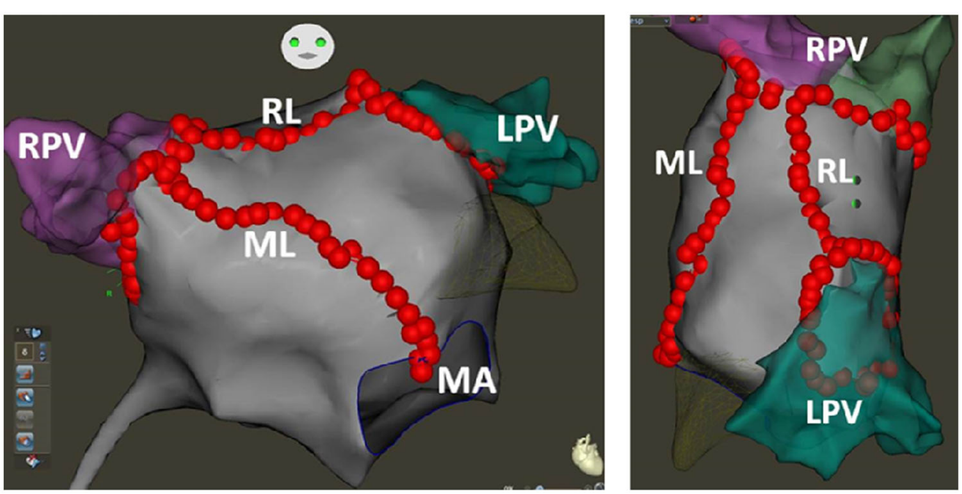


Figure 1. Anteroposterior (left) and superior (right) views of the left atrium after pulmonary vein isolation, anterior mitral line and roof line ablation. The red points are the ablation tags. RPV: right pulmonary veins; ML: mitral line; RL: roof line; LPV: left pulmonary veins; MA: mitral annulus.

### Posterior wall isolation

Isolation of the posterior wall ('posterior box isolation') of the atrium was performed by adding an inferior ablation line to a roof line. The catheter was moved from the infero-posterior limit of the ostium of the left inferior pulmonary vein to the adjacent ostium of the inferior right pulmonary vein, or vice-versa. For the posterior segment of the PV, we applied 25 W, with a target FTI of 200 g·s. Image B shows an example of posterior box isolation. If the patient was still in AF after these linear ablations, we restored sinus rhythm with electrical cardioversion before validating that the lines were electrically blocked.

### Validation of the pulmonary veins and posterior box isolation

Isolation of the pulmonary veins and the posterior box was defined by the absence or dissociation of electrograms within (entry block) and the absence of atrial depolarisation when stimulating from inside the veins or in contact with the posterior wall (exit block). PVI has been described in detail in our previous report [6]. The same principle was applied for posterior box isolation (Figure 2).

### Validation of the mitral isthmus and roof lines

Validation of the conduction block across the mitral line was made by pacing from the left atrial appendage (LAA) or from its base with the ablation catheter and observing a distal-to-proximal activation pattern on the Halo inserted into the coronary sinus. This activation pattern was reversed when pacing from both sides of the line (Figure 3). This validation technique has already been described [4,7]. Without a CMC, this method is only valid when the Halo is inserted far enough in the coronary sinus, at least further that the '6 o-clock' region of the sinus is in a left lateral view (Figure 4).

For the roof line, we considered a block if we observed an ascending (from caudal to cranial) activation of the posterior wall in sinus rhythm or while pacing from an anterior region (for example, the distal part of the coronary sinus if the Halo is inserted far enough within), as previously described [7]. Figure 5 shows an example of a blocked roof line proved by an activation map. Another way of proving the block is to record the Halo activation delay when pacing from the posterior wall: pacing from the upper part of the wall (close to the roof line) will induce a later activation of the Halo than pacing from the lower part of the wall. Of course, if the posterior box is successfully dissociated, we know that the roof line is blocked.

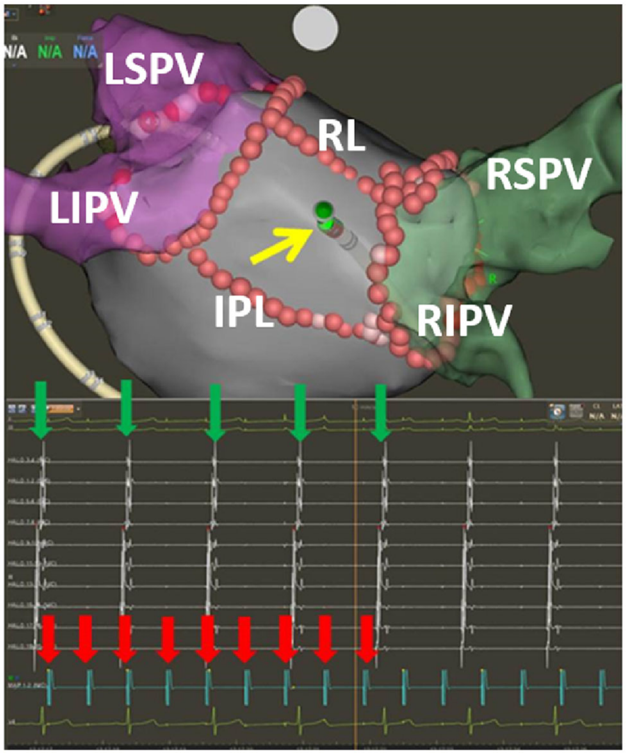


Figure 2. Posterior view of the left atrium after PVI and successful posterior box isolation. While pacing from the ablation catheter (yellow arrow), which is in contact with the posterior wall, the atrial rhythm recorded on the duodecapolar catheter (green arrows) is independent of the pacing from the catheter ablation (red arrows). LSPV: left superior pulmonary vein; LIPV: left inferior pulmonary vein; IPL: infero-posterior line; RSPV: right superior pulmonary vein; RIPV: right inferior pulmonary vein.

In addition to these ablation strategies, patients who showed typical atrial flutter (before or during the procedure) also underwent ablation of the cavo-tricuspidian isthmus.

### Follow-up

At 3 months, anticoagulation therapy was continued according to the stroke risk, whereas antiarrhythmic drug therapy (ADT) was continued at the discretion of the treating physician. Freedom from recurrence was defined as 1 year of absence of AF/atrial flutter (AF/AFL) >30 s (after a blanking period of 3 months). Holter monitoring was performed at the discretion of the treating physician or in cases of suspected AF recurrence.

### Statistical analysis

The results of statistical analysis are expressed as mean ± standard deviation. Comparisons between

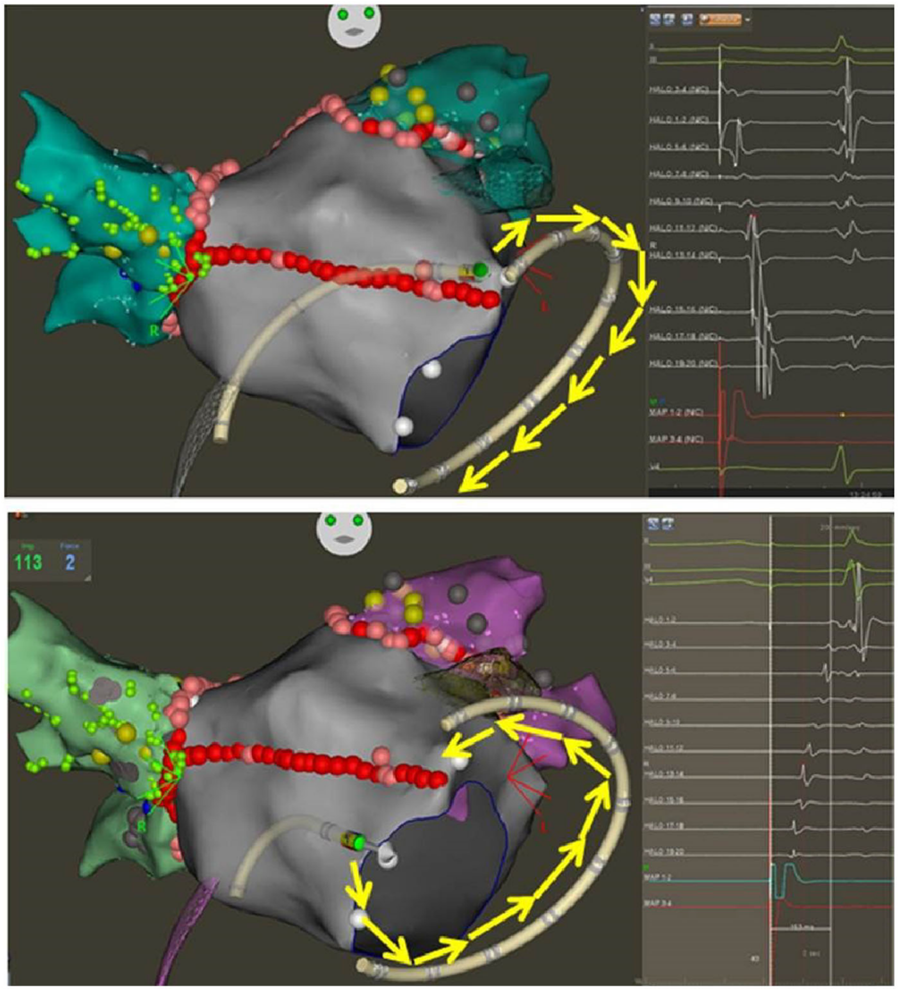

Figure 3. Anterior view of the left atrium illustrating a bidirectional block across the mitral isthmus. On the upper part, a counter-clockwise block: pacing from the ablation catheter upside of the mitral line (close of the LAA appendage) shows a distal-to-proximal activation pattern of the duodecapolar catheter (from Halo 1, distal, to Halo 10, proximal). On the lower part, clockwise block: pacing of the ablation catheter from downside of the mitral line shows a reversal of the activation pattern, which becomes proximal-to-distal (Halo 1 is the latest electrode activated). On both images, yellow arrows mark the direction of the duodecapolar catheter activation.

variables were performed using the Chi-squared test. A $p$-value $<0.05$ was considered statistically significant.

## Results

All 261 patients had persistent AF (defined by episodes lasting at least 7 days), and none had undergone AF ablation before. The initial characteristics of the patients are listed in Table 1.

### *Procedural characteristics*

The average procedure time was 136.5 min (±45.6 min). The average fluoroscopy time was 144.1 s (±116.4 s) for a mean dose-area product (DAP) of 2018 mGy·cm$^2$ (±2341 mGy·cm$^2$). All patients had PVI. A total of 153 (59%) patients had anterior mitral isthmus ablation, 129 (49%) underwent posterior box isolation, and 45 (17%) had a roof line ablation without encircling the posterior box. All procedural characteristics are listed in Table 2.

### *Safety*

One patient showed a pseudoaneurysm that required surgical intervention and two showed an arteriovenous fistula that was treated medically (extended femoral compression). One patient had a pericardial effusion but did not require drainage. We did not observe any tamponade or atrioesophageal fistula.

### *Follow-up findings*

All patients underwent clinical follow-up assessments for one year. A total of 110 patients (42%) underwent

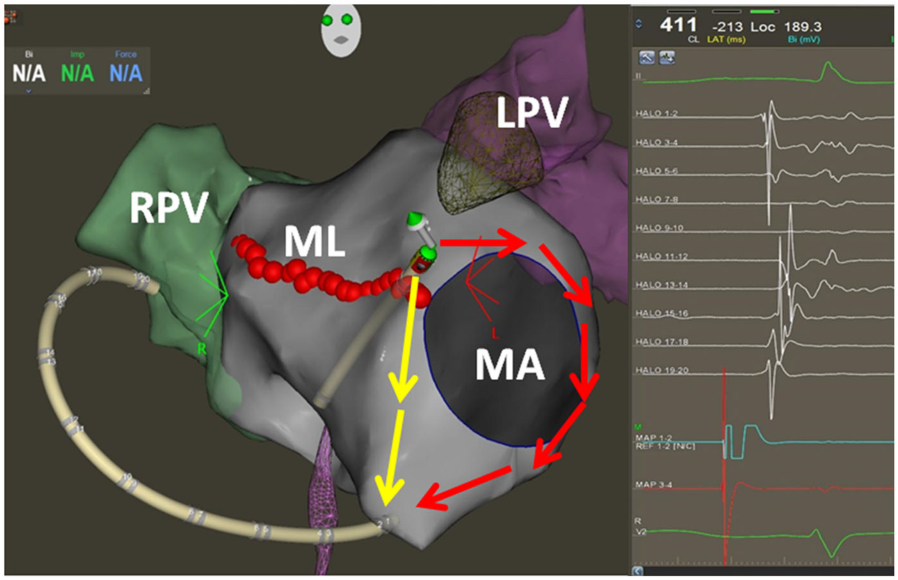


Figure 4. Left lateral view of the left atrium after having performed a mitral line. In this case, the Halo is at the ostium of the coronary sinus, not far enough within to prove the conduction block across the mitral isthmus. Indeed, when stimulating from the base of the left appendage, Halo 1 will be the first reached electrode and the depolarisation pattern will be the same either the line is blocked (red arrows) or not (yellow arrows).

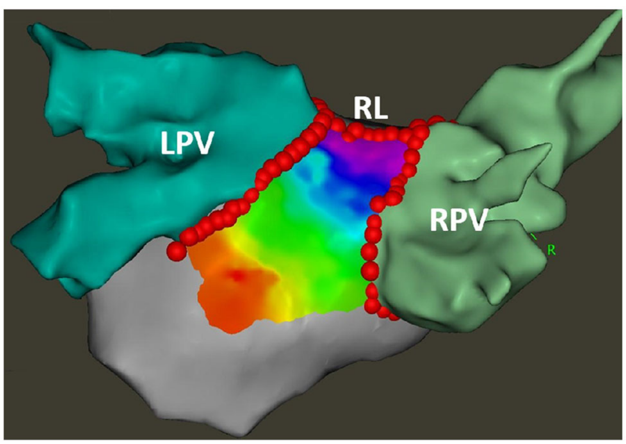


Figure 5. Posterior view of the left atrium after PVI and roof line, with an activation map of the posterior wall. For this activation map, pacing from the distal coronary sinus (close to the LAA), we measured the activation timing in several locations on the posterior wall, after which the software assigns different colours according to the delay, from the most premature (in red) to the latest activated region (in purple). The map shows an ascending activation pattern of the posterior wall, confirming the electrical block across the roof line.

a rhythm recording of at least 24 h. After 1 year, with this single ablation procedure, recurrence of AF or AFL occurred in 73 of the 261 patients (28%). AF recurrence was documented in 51 patients (20%) and AFL in 22 patients (8%). All recurrences were proven by a 12-lead ECG and/or another rhythm recorder. At one year, 90 patients (34%) were on antiarrhythmic medication. The follow-up findings are presented in Table 3.

Table 1. Initial characteristics of the patients.

| | |
|---|---|
| Total | 261 |
| Men | 71% (185/261) |
| Age (years) | 65.7 ± 9.2 |
| BMI (kg/m$^2$) | 30.4 ± 6.2 |
| First AF episode (years) | 3.8 ± 4.2 |
| Symptomatic AF | 73% (190/261) |
| Number of AAD tested | 1.2 ± 0.7 |
| Left atrial volume (mL)* | 130 ± 35.7 |
| Arterial hypertension | 58% (152/261) |
| Diabetes | 18% (46/261) |
| Ischemic cardiomyopathy | 16% (43/261) |
| Prior embolic event | 11% (30/261) |
| Hypertrophic cardiomyopathy | 5% (12/261) |
| Valvular cardiomyopathy | 14% (36/261) |
| Heart failure | 25% (64/261) |
| Age >75 years | 16% (42/261) |
| Age 65–74 years | 41% (108/261) |
| CHADS$^2$ VA$^2$S score | 2.5 ± 1.5 |

BMI: body mass index; AF: atrial fibrillation; AAD: anti-arrhythmic drug.
Data are expressed as % (*n*) or mean ± standard deviation.
*Left atrial volume is the volume of the 3D shell reconstructed during the procedure.

## Discussion

### *Main findings*

This report aimed to share our experience and prove the feasibility of persistent AF catheter ablation without a CMC. We have already shown that a CMC is not mandatory for PVI alone [6]. Although the addition of LAL in PVI while performing persistent AF ablation is a matter of debate, we aimed to show that more extensive ablation strategies are also feasible without a CMC.

The challenge created by the absence of a CMC is the validation of the conduction block across the lines.

Posterior box isolation is easy to prove without a CMC, showing an exit block while pacing from inside the box with the ablation catheter or an entry block in sinus rhythm (absence or dissociation of the electrical activity inside the box).

**Table 2.** Procedural characteristics and ablation targets.

| | |
|---|---|
| Procedure duration (min) | 136.5 ± 45.6 |
| Fluoroscopy time (s) | 144.1 ± 116.4 |
| DAP (mGy.cm$^2$) | 2018 ± 2341 |
| Ablation targets | |
| **Pulmonary vein isolation** | **100% (261/261)** |
| Successfully isolated | 99% (260/261) |
| **Mitral isthmus ablation** | **59% (153/261)** |
| Non-assessed mitral lines | 28% (43/153) |
| Assessed mitral lines | 72% (110/153) |
| Blocked mitral lines | 80% (88/110) |
| Non-blocked mitral lines | 20% (22/110) |
| **Posterior box isolation** | **49% (129/261)** |
| Successfully isolated | 59% (76/129) |
| **Roof line ablation** | **67% (174/261)** |
| Non-assessed roof lines | 21% (36/174) |
| Assessed roof lines | 79% (138/174) |
| Blocked roof lines | 89% (123/138) |
| Non-blocked roof lines | 11% (15/138) |
| **Cavo-tricuspid isthmus ablation** | **34% (90/261)** |

DAP: dose-area product.
Data are expressed as % (*n*) or mean ± standard deviation.
Bold values describe ablation targets, which may differ between procedures.

**Table 3.** One-year follow-up.

| | |
|---|---|
| Total | 100% (261/261) |
| Freedom from AF/AFL | 72% (188/261) |
| Patients on antiarrhythmic drug therapy | 34% (90/261) |
| AF recurrences | 20% (51/261) |
| AFL recurrences | 8% (22/261) |
| Success rate among patients with roof line ablation | |
| Total | 70% (108/153) |
| Non-assessed mitral line | 67% (29/43) |
| Assessed mitral line | 72% (79/110) |
| Blocked mitral line | 76% (67/88) |
| Non-blocked mitral line | 55% (12/22) |
| Success rate among patients with roof line ablation | |
| Total | 73% (127/174) |
| Non-assessed roof line | 72% (26/36) |
| Assessed roof line | 73% (101/138) |
| Blocked roof line | 76% (94/123) |
| Non-blocked roof line | 47% (7/15) |

AF: atrial fibrillation; AFL: atrial flutter.
Data are expressed as % (*n*).

For the mitral isthmus, we were occasionally unable to assess the conduction block if we could not insert the duodecapolar catheter far enough in the coronary sinus to see the reversal of its activation pattern. We performed mitral isthmus ablation in 153 patients (59% of the total) and were able to check the conduction block in 110 (72% of the patients who underwent mitral isthmus ablation). We classified these 110 patients into the 'Assessed mitral line (ML) group' and the other 43 patients into the 'Non-assessed ML group.' Of the 110 tested lines, 88 (80%) were blocked, which is comparable to that described in a previous report [7]. Nevertheless, at the 1-year follow-up, the ablation success rate in the 'Assessed ML group' did not significantly differ from that in the 'Non assessed ML group' (72 *vs.* 67%, $p = \mathrm{NS}$). This finding suggests that, even if not assessed, a comparable number of mitral lines created are probably blocked in both groups. This highlights the importance of carefully ablating along the lines, avoiding any gap, and delivering a sufficient ablation power (even in the optimal power goal is not established for anterior lines). Indeed, in the 'Assessed ML group,' the success rate was lower (although not significantly, but this is probably due to the small number of events) if we could not obtain electrical block across the line, as it has already been suggested [4]. Figure 6 illustrates the success rates among the patients who underwent mitral line ablation.

For roof lines, we were able to test the conduction block for 138 of the 174 lines created ('Assessed Roof Lines [RL] group'). In this group, 121 lines (88%) were blocked. This rate is quite similar to that reported previously [7,8]. Assessment of the block is easier if the posterior box is encircled. If we consider only the 45 patients who received a roof line without an inferoposterior line, we were able to test the block in 26 (51%) patients (21 showed a block and 5 did not). As

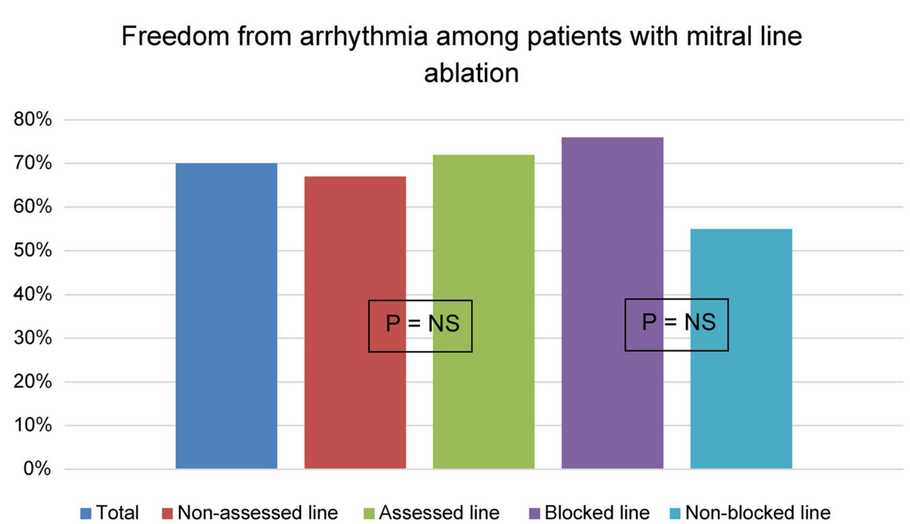


**Figure 6.** Freedom from arrhythmia among patients with mitral line ablation.

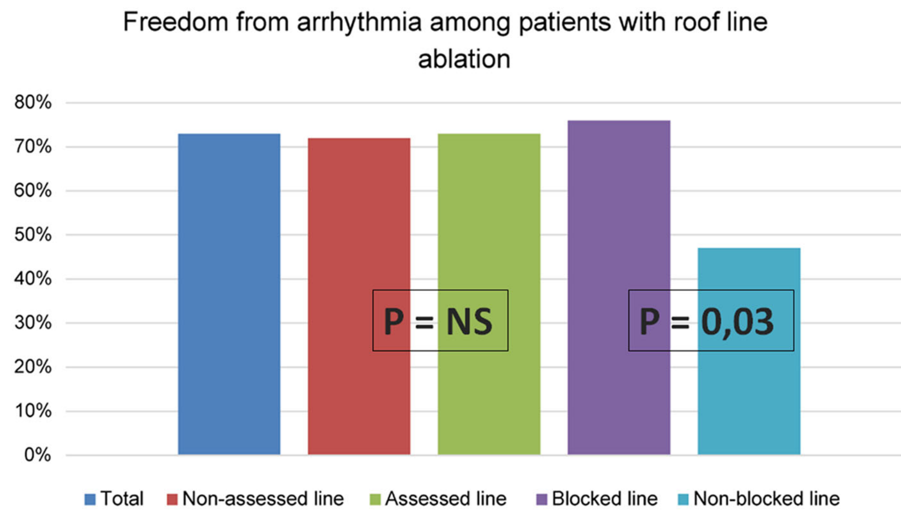


**Figure 7.** Freedom from arrhythmia among patients with roof line ablation.

for the mitral isthmus, ablation success rates did not seem to differ depending on whether the roof line was assessed of not (73 *vs.* 72%, $p = \text{NS}$), suggesting that a similar number of lines are probably blocked in the two groups. Indeed, in the 'Assessed RL group,' the success rate was higher if the line was blocked compared to that if it was not (76 *vs.* 47%, $p = 0.03$). Figure 7 illustrates the success rates among the patients who underwent mitral line ablation.

In summary, the absence of CMC does not appear to influence the success rate of ablation, since our success rate of 72% was quite similar to that reported in other studies [7]. However, it is difficult to establish a comparison with other reports because of the large variety of ablation strategies used in persistent AF ablation and the spectacular improvements in RF technology in the last few years (with the development of contact-force technology, ablation index, etc.). Thus, we do not presume to thoroughly compare our cohort with others. We suggest that prospective and comparative studies should be conducted to ensure that there is no loss in efficacy or safety. The absence of a CMC allows us to avoid one femoral puncture, one transseptal puncture, and reduce the manipulation of the catheters in the left atrium, which should lower the procedure duration and fluoroscopy use, as has already been shown for paroxysmal AF [6]. Further, depending on the reimbursement model of the country, avoiding the use of the CMC may significantly reduce the cost of the procedure.

### Limitations

This study had several limitations. First, it was a registry study based on a single-centre experience, which reduced its statistical power. However, our goal was to share our experience and propose that persistent AF ablation is feasible without a CMC and not to compare the findings with other reports. We suggest that prospective studies should be conducted to evaluate the gains in time, safety, and reduced fluoroscopy use due to the absence of the CMC.

Second, the recurrence of AF was evaluated by clinical follow-up (patient interviews, ECG, Holter ECG), which can underestimate AF recurrence. In clinical practice, systematic Holter recordings are less likely to be performed to prove recurrence of persistent AF, since absence of symptom and 12 lead ECG showing sinus rhythm may be considered as reassuring. Despite this methodological limitation, previous studies on feasibility used this methodology for the evaluation of an ablation protocol [5,9].

Third, the absence of AI at the time of ablation did not allow for the evaluation of the ablation line contiguity index (ALCI) proposed by El Haddad et al. [10]. A more precise analysis of the optimal AI is therefore not possible in this study, but would also be interesting, especially for linear ablations in the anterior wall of the left atrium, where it remains unknown.

### Perspectives in radiofrequency AF ablation

AF recurrence remains too frequent after ablation, especially in persistent AF. Beyond PVI, the optimal ablation strategy has yet to be established, since prospective and randomised large studies showing the superiority of more extensive ablation procedures (for example performing left linear ablations, targeting fractionated electrograms, rotors) still lack. Maybe the upcoming STAR AF III trial will bring a new perspective on this debate.

Some new ablation technologies have recently emerged, that hopefully will help us improving success rates and safety of ablation. For radiofrequency ablation, the 'high power-short duration' technique has already proven to create wider but less deep ablation lesions, which should limit the risks of oesophageal thermal injury. As each lesion requests shorter time, the total duration of the ablation is also reduced by this technique [11]. A new and promising ablation energy is the irreversible electroporation (IRE), which consists of direct high voltage current application, for extremely short duration (a few milliseconds). This high voltage current creates pores through the cell's membrane, leading to its death by loss of membrane's function. The great advantage of this technique is that each cell has its own threshold of voltage sensibility, allowing to target the cardiomyocytes only and not to harm the adjacent structures (such oesophagus, phrenic nerve) and to avoid pulmonary vein stenosis. Again, as the ablation duration is shortened with this technique, this could help reducing the total procedure time. Some recently published studies have already shown the feasibility and safety of this new and promising ablation technique [12,13].

## Conclusion

In our clinical experience, persistent AF ablation is safe and effective in sinus rhythm maintenance. In our experience, limiting the realisation of left atrial linear lesions to patients with very large left atrium and/or long lasting AF episodes seems to be a reasonable and effective method, but this topic remains a matter of debate.

Performing the ablation without the use of a CMC avoids one femoral and one transseptal puncture and, depending on the reimbursement model of the country, can significantly reduce the cost of the procedure. The only inconvenience in our experience is a small lack of capacity to test the left atrial roof and mitral lines, but this does not seem to influence the efficacy of the ablation. Furthermore, this method should probably be able to reduce the procedural duration and use of fluoroscopy, with no apparent loss of efficacy, but we suggest that this should be assessed by prospective, randomised studies.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

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