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CLINICAL RESEARCH
Cardiac electrophysiology

Ablation of perimitral flutter: acute and long-term success of the modified anterior line

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Aims The modified anterior line (MAL) is an alternative to the mitral isthmus (MI) line for the treatment of perimitral atrial flutter (PMFL). We sought to investigate acute and long-term efficacy of this line if routinely used for PMFL.

Methods and results The cohort included 77 consecutive patients who underwent catheter ablation of PMFL. The anterior line was deployed between the anterolateral mitral annulus and the ostium of the left superior pulmonary vein. Perimitral atrial flutter was either the presenting arrhythmia after persistent atrial fibrillation (AF) ablation (Group 1, $n = 42$, 54.5%), occurring during AF ablation (Group 2, $n = 25$, 35%) or presenting as primary arrhythmia (Group 3, $n = 8$, 10%). Acute success was defined as PMFL termination during MAL deployment with demonstration of bidirectional line block. Acute success was achieved in 68 of 77 patients (88%) without difference between the three groups. In five patients an additional MI line was necessary to terminate PMFL and in four patients both lines failed to achieve termination. During follow-up (16 ± 7 months), 38 of 77 (49%) patients underwent a repeat procedure for a recurrent arrhythmia. During reablation, 13 of 38 (34%) patients were identified to have a PMFL recurrence. Persistent MAL block was demonstrated in 22 of 38 (58%) patients during the repeat ablation.

Conclusion The MAL is effective for acute and long-term treatment of PMFL. Maintenance of bidirectional MAL block was shown in 58% of patients during a repeat ablation.

Keywords Perimitral flutter • Ablation • Line • Atypical flutter • Modified anterior linie

Introduction

Left atrial tachycardias (ATs) are quite a common arrhythmia after persistent atrial fibrillation (AF) ablation.[1,2] Using a stepwise approach, ATs frequently represent an intermediate tachycardia during persistent AF ablation before achieving sinus rhythm.[3] Primary ATs are rare and are seen mostly in scarred atria after cardiac surgery. In all cases, ablation is challenging because of the difficulty to create continuous and dense lesions.

Macroreentries around the mitral annulus are a frequent left AT mechanism. In perimitral flutter (PMFL), the strategy most often used is to create a linear lesion between the left inferior pulmonary vein (LIPV) and the mitral annulus [mitral isthmus (MI) line].[4] However, this line can be technically demanding due to anatomical issues.[5,6]

In 2010, we had described an alternative to the MI line. We used a modified anterior line (MAL) connecting the anterior/anterolateral mitral annulus with the left superior pulmonary vein (LSPV).[7] Reports regarding long-term success and maintenance of block relate to a small number of patients for the MI line and are lacking for the MAL.[8,9]

In this study, we therefore sought to investigate acute and long-term efficacy of the MAL and evaluated the rate of permanent MAL bidirectional block.

Methods

Study population

The cohort included 77 consecutive patients (mean age 66 ± 9 years, 73% male, mean LA diameter: 46 ± 6 mm; see *Table 1* for baseline characteristics) who underwent catheter ablation of PMFL using a MAL between January 2010 and January 2013 at two centres. Perimitral atrial flutter was confirmed using entrainment maneuvers and/or a 3D activation mapping.[1,10] A circular mapping catheter was placed in the

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What's new?

- The modified anterior line (MAL) can be a useful alternative to the mitral isthmus line for treatment of perimitral flutter. The MAL encounters less endocardial obstacles, facilitating transmural lesion creation and avoiding ablation into the coronary sinus.
- This study offers long-term results for treatment of perimitral flutter. The MAL was shown to be effective during follow-up, with maintenance of bidirectional MAL block in 58% of patients.

left atrial appendage (LAA) to monitor tachycardia cycle length (TCL) during the procedure. Entrainment pacing was performed at the proximal and distal coronary sinus (CS), at the anterior or lateral mitral annulus and if necessary at other segments of the left and right atrium. The difference between the post-pacing interval (PPI) and the TCL was calculated at the different regions.

Perimitral atrial flutter was defined as a stable AT with PPI-CL < 30 ms in at least two segments of the mitral annulus. If TCL and/or CS sequence changed during RF application, entrainment maneuvers were repeated to rule out other AT mechanisms.

Perimitral atrial flutter was either the presenting arrhythmia after persistent AF ablation (Group 1, $n = 42$, 54.5%), occurring during AF ablation (Group 2, $n = 25$, 35%) or presenting as a primary arrhythmia (Group 3, $n = 8$, 10%). Persistent AF ablation consisted of PV isolation combined with the ablation of complex fractionated atrial electrograms (CFAEs) which was followed by mapping and ablation of subsequent ATs.

Ablation strategy

Isolation of the left PV was performed as an initial step. If PV isolation had been performed during a first procedure, all PVs were rechecked and isolated again if reconnected. In a second step, the MAL was deployed.[7] The anterior mitral annulus was connected to the ostium of the LSPV (*Figure 1*). Ablation was performed using a 3.5 mm open irrigated tip ablation catheter (Therapy Cool Path Duo™ or Thermocool® SF Catheter) using a standard setting of 35 W, with a temperature limit of 43°C and a perfusion rate of 30 mL/min (15 mL/min for SF Catheter). The ablation catheter was advanced through the transseptal puncture without use of a long sheath: the transseptal sheath was withdrawn to the right atrium to facilitate the passage of the ablation catheter to the left atrium through the same puncture point. If a line of block was not achieved with standard settings, a power titration of up to 40 W was performed with a perfusion rate increased to 40 mL/min and/or a steerable sheath was used to enhance contact and stability.

Radiofrequency ablation was started with an atrioventricular electrogram ratio of 1:2 at the anterior part of the mitral annulus. The line was performed with counterclockwise rotation and progressive release of the ablation catheter curve. The lesion was continued to the anterior part of the LAA orifice and then connected to the LSPV.

Assessment of bidirectional modified anterior line block

Conduction block across the MAL was assessed by bidirectional differential pacing. In brief, the circular mapping catheter was placed in the LAA (lateral of the line) and the ablation catheter directly septally to the line. Then, the activation sequence on the anterior and septal LA wall during LAA pacing was assessed. Activation was expected to be septally to laterally in case of a complete block (*Figure 2A*). Vice versa, the activation of the LAA and distal CS was assessed during pacing directly septally to the line via the ablation catheter. Complete block was assumed when LAA activation occurred later than distal CS activation and when the interval to LAA activation was longer, the closer to the line the pacing was performed (*Figure 2B*). Further evidence of MAL block was provided by the observation of widely spaced double potentials along the MAL during pacing from the LAA.

Atrial tachycardia persistence after modified anterior line deployment

If tachycardia persisted after MAL deployment, entrainment maneuvers and/or activation mapping were repeated to confirm or rule out PMFL. If PMFL was still confirmed, a MI line was deployed between the ostium of LIPV and the lateral mitral annulus. If MI line block was not achieved after extensive endocardial ablation with disappearance of endocardial potentials or split electrograms along the line, ablation was performed inside the CS using the irrigated-tip catheter at a maximum power of 30 W.

If PMFL was still confirmed with entrainment maneuvers and/or activation mapping, even after the alternative strategy, electrical cardioversion was performed. If PMFL changed into another AT form, this AT was ablated until sinus rhythm was achieved.

Table 1 Baseline characteristics

Mean age (years)	66 + 9 years
Male (*n*, %)	56 (73)
Coronary artery disease (*n*, %)	13 (17%)
Diabetes mellitus (*n*, %)	12 (16)
Arterial hypertension (*n*, %)	57 (74%)
Mean LA diameter (mm)	46 ± 6 mm
Ejection fraction < 45% (*n*, %)	8 (10%)
Heart valve surgery (*n*, %)	2 (2.5%)

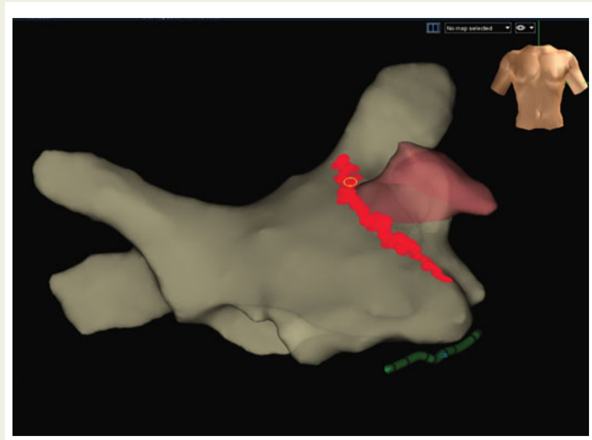

Figure 1 Anteroposterior view of three-dimension anatomical map of the left atrium (NavX, St. Jude Medical). The MAL is deployed between the anterolateral mitral annulus and the ostium of the LSPV.

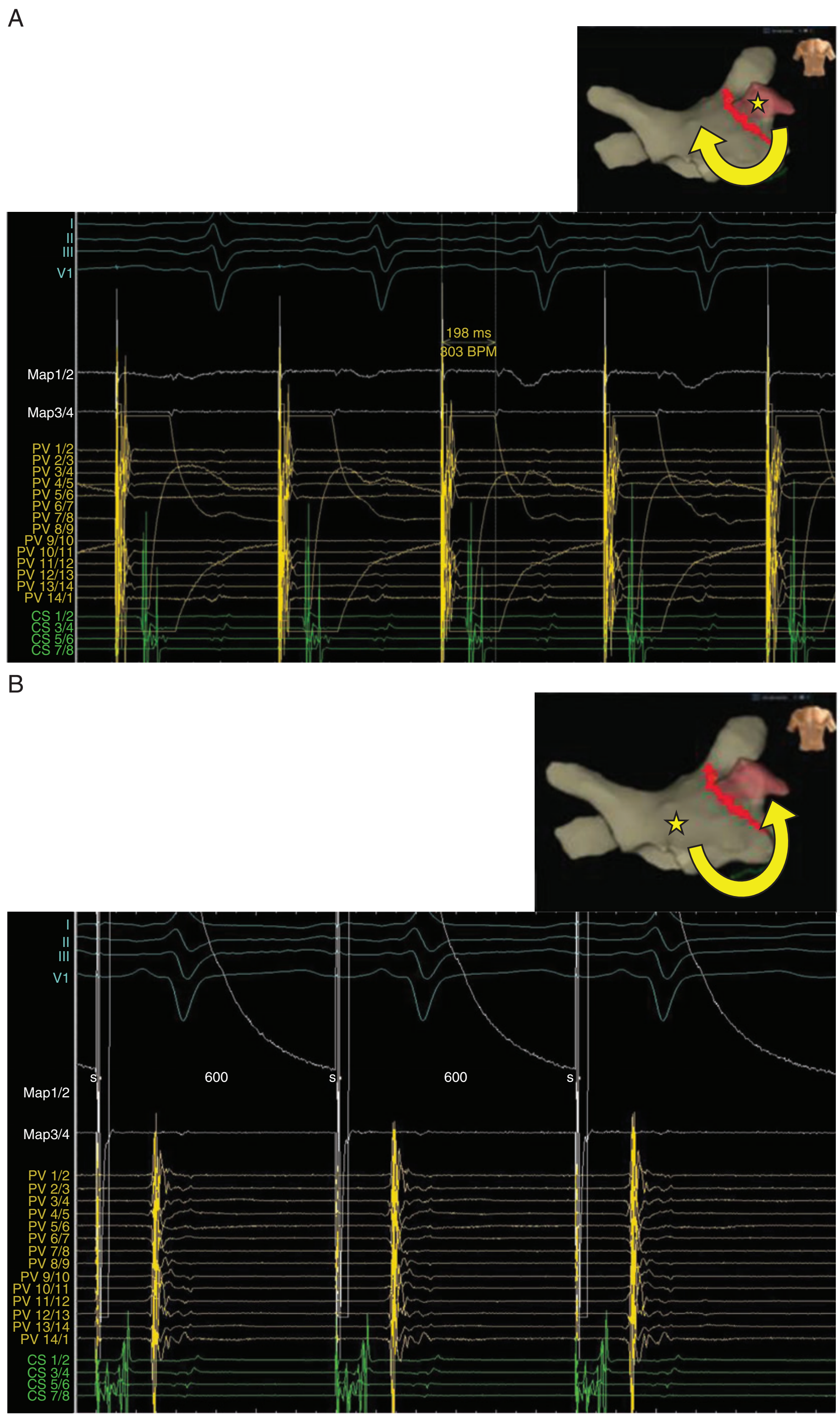

Figure 2 Demonstration of MAL bidirectional block. (*A*) Demonstration of lateral to septal MAL conduction block: radiofrequency catheter is positioned directly on the MAL line, a circular 14-polar mapping catheter in the LAA and a 8-polar catheter in the coronary sinus. During pacing from LAA, the delay from the pacing artefact to the atrial potential on the RF catheter is 198 ms and was 160 ms if RF catheter was moved more septally to the line. Note the widely spaced double potentials along the MAL. (*B*) Demonstration of septal to lateral MAL conduction block: radiofrequency catheter is positioned septally to the MAL line, a circular 14-polar mapping catheter in the LAA and an 8 polar catheter in the coronary sinus. Pacing performed septally to the line results in an activation of the (distal) coronary sinus before activation of the LAA.

Acute success

Acute success was defined as PMFL termination into sinus rhythm or conversion into another non-perimitral tachycardia during ablation and the subsequent confirmation of a bidirectional line block. Perimitral atrial flutter termination without achievement of bidirectional MAL block or the need of a MI line was considered as failure.

Follow-up

Patients were followed using repetitive 7 day Holter ECG's every 3 months and in case of symptoms. Every AT episode documented more than 4 weeks after ablation was considered as a recurrence. During the first 2 months after ablation, electrical cardioversion was performed in case of recurrence. If a recurrence occurred more than 2 months after the ablation, reablation was recommended. During reablation, all deployed lines were tested for bidirectional block.

Statistical analysis

Quantitative data are presented as mean ± standard deviation, qualitative data as absolute and relative frequencies. For statistical tests a two-sided level of significance of $\alpha = 0.05$ was used. Comparisons between groups were made by χ^2 test or Fisher's exact test for categorical variables and unpaired t test or one-way analysis of variance for continuous variables.

Results

Acute results

Mean TCL was 271 ± 65 ms. Acute success was achieved in 68 of 77 (88%) patients. No difference was seen between the three groups (81%, 96%, and 100% in Groups 1, 2, and 3, respectively, $P = 0.11$). In nine patients (12%), an additional MI line was deployed with ablation inside the CS in seven of nine patients. The MI line terminated PMFL after MAL failure in five of nine patients (five patients of Group 1). In four of nine patients (three of Group 1 and one patient of Group 2), both lines failed to achieve PMFL termination. Possible reasons for MAL failure could be found in only three patients of Group 1 with a large LAA insertion at the mitral annulus and in one patient of Group 2 with possible edema after CFAE ablation at the anterior wall.

A steerable sheath was used for lesion deployment in 12 MAL and 5 MI lines.

Mean procedure time, RF time, and fluoroscopy time were 172 ± 72, 59 ± 31, and 30 ± 19 min, respectively, without significant difference between groups *Table 2*. Complications included one pericardial tamponade during MAL deployment and one during roof line deployment. Both were managed by pericardial drainage. In one patient with a successful ablation an electrical LAA isolation was noted.

Long-term results

During a mean follow-up of 16 ± 7 months, 39 of 77 (51%) patients remained in sinus rhythm without use of any antiarrhythmic drug. Thirty-eight of 77 (49%) patients with documented ATs underwent a repeat procedure.

The main electrophysiological findings during reablation in the three groups are summarized in *Table 3*: 13 of 38 (34%) patients had PMFL as clinical arrhythmia. A gap in the MAL was diagnosed in all these patients [8 of 20 (40%) in Group 1, 4 of 17 (24%) in Group 2 and 1 of 1 (100%) in Group 3, $P = 0.16$]. Reablation was performed with demonstration of a MAL block in all patients. In 25 of 38 (66%) patients, other AT forms (not related to the MAL) were found and ablated.

In two of nine (22%) patients in whom a MI line was performed, PMFL recurrence due to a gap was diagnosed. Reablation was successful in these two patients.

During the repeat procedure, a bidirectional MAL block was confirmed in 22 of 38 (58%) of patients [10 of 20 (50%) of Group 1 and 12 of 17 (71%) of Group 2, $P = 0.2$]. In 3 of 38 (8%) patients (two in Group 1 and one in Group 2), the MAL had recovered although these patients had no clinical PMFL recurrence.

Discussion

This study shows that the MAL is effective for acute and long-term treatment of PMFL. Maintenance of bidirectional MAL block was demonstrated during a repeat ablation in 58% of patients.

Modified anterior line compared with mitral isthmus line: acute success and challenges

Achievement of bidirectional block using the MI line is challenging. In recent studies, MI block was achieved only in 65% to 76% of patients.[11–13] Creation of a transmural lesion is often impossible with endocardial ablation because of complex anatomy, the thickness of the myocardium and the cooling flow of the CS and the circumflex artery.[5,14–16] More than two-third of patients require ablation inside the CS to achieve complete line block.[17] Tricks to enhance block probability are high energy delivering up to 50 W, use of a steerable sheath[18] and temporary occlusion of the CS.[13] Even with this maneuvers success was not improved[13] and could attain 91% in only one study.[18] Additionally, the assessment of bidirectional block encounters some pitfalls[17,19,20] which might explain the variable success rates between 65% and 92%.[4,13,20] Ablating deep inside the CS may result in a higher complication rate including coronary spasm or occlusion, dissection of the CS and cardiac tamponade.[18,21,22]

The data of this study confirm results concerning safety and feasibility of the MAL. Using this line, bidirectional block assessed by rigorous criteria was achieved in 88% of patients and only 9% of patients required ablation inside the CS after failure of the MAL. The MAL is longer than the MI line but encounters less endocardial obstacles such as diverticula and pouches, which facilitates transmural lesion creation with a lower amount of RF energy.[5,6] Thus, a MAL block could be achieved with standard settings and without the use of a steerable sheath in a majority of patients in our study. However, in rare cases the use of a sheath can be helpful, e.g. in case of instability in large atria or in case of high atrial voltage to enhance contact and achieve a better lesion.

Possible reasons for failure of the MAL in our experience are large insertion of the LAA at the mitral annulus and oedema due to prior CFAE ablation in this region. Owing to lack of data, we can only speculate to what extent wall thickness at the LAA root influences additionally the success of this line. In four patients both lines failed. We could not identify any predictive factor for this double failure.

Table 2 Procedural data

	Group 1 (AT after persistent AF ablation, $n = 42$)	Group 2 (AT occurring during AF ablation, $n = 25$)	Group 3 (primary AT, $n = 8$)
Acute success (%)	81%	96	100
Procedure time (min)	170 ± 75	178 ± 67	161 ± 83
RF time (min)	53 ± 32	70 ± 26	58 ± 33
Fluoroscopy time (min)	26 ± 16	36 ± 22	31 ± 20

Table 3 Electrophysiological findings during reablation procedure

	Group 1 (AT after persistent AF ablation, $n = 42$)	Group 2 (AT occurring during AF ablation, $n = 25$)	Group 3 (primary AT, $n = 8$)	*P*
Repeat ablation (*n*, %)	20/42 (48%)	17/27 (63%)	1/8 (12%)	0.037
Recurrence of perimitral flutter as clinical arrhythmia (*n*, %)	8/20 (40%)	4/17 (24%)	1/1(100%)	0.16
Persistent MAL block during reablation (*n*, %)	10/20 (50%)	12/17 (71%)	–	0.2

Electrical LAA isolation might be a problem in patients with a combination of MAL and MI line. It can occur if both lines are blocked or in patients with extended CFAE ablation in the septal region resulting in transsection of the Bachmann's bundle. Compared with the medially performed anterior line connecting the right superior PV to the mitral annulus,[23] the MAL avoids the proximal branches of the Bachman's bundle and thereby alteration of atrial activation.[24]

Modified anterior line: long-term results and maintenance of block

There are few data concerning long-term results of PMFL ablation. In our study, the overall PMFL recurrence during follow-up was relatively low as most of recurrences were due to other AT forms. Data regarding long-term maintenance of block and consequences of conduction recovery are lacking. It is well known that lines can be arrhythmogenic. In a study of Matsuo *et al.*,[8] PMFL was more frequent during follow-up if a MI line was performed during AF ablation (41% vs. 15%, $P < 0.01$). In a study of Anousheh *et al.*,[9] the risk of PMFL was four times higher if block of the MI line was not achieved during first procedure. This study also showed that, despite a high acute rate of MI line block (83%), four of seven patients had a PMFL recurrence due to recovery of conduction across the MI line. In a study of Wong *et al.*,[17] who used a steerable sheath and high power for ablation, reconduction of the MI line was documented in 44% of redo procedures.

Long-term maintenance of bidirectional MAL block was present in 58% of patients during the repeat ablation. A gap in the line was responsible for the clinical recurrence of PMFL in 34% of patients. In 3 of 38 (8%) patients, the MAL had recovered although these patients had no clinical PMFL recurrence. Montenero *et al.*[25] who assessed maintenance of block 3 months after ablation of the cavotricuspid isthmus for typical flutter, also found a 31% rate of isthmus reconduction in clinically asymptomatic patients.

Limitation

Success rates might be enhanced as only experienced operators in two centers conducted the procedures. We do not know if these operators could have similar results in the MI line. Thus, a randomized trial investigating the acute and long-term results of the MAL in comparison to the MI line would be of great value. Moreover, MAL block was checked during follow-up only in patients who underwent a repeat ablation. Therefore, the 'true' recovery rate of the MAL in clinically asymptomatic patients is unknown.

Conclusion

Treatment of PMFL using the MAL with a procedural endpoint of bidirectional conduction block is feasible in 88% of patients. During follow-up, this strategy shows a low incidence of PMFL recurrence and a 58% rate of maintenance of MAL block in patients who underwent a repeat ablation. Therefore, the MAL might be considered as alternative to the MI line for PMFL.

Conflict of interest: none declared.

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