

Review Article

Atrial Tachycardia After Ablation of Atrial Fibrillation: Ten Steps to Diagnosis and Treatment

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During the last decade, mounting evidence has validated the superior efficacy of ablation in comparison to pharmacological treatment in preventing recurrences of atrial fibrillation (AF).¹⁻⁵ A sequela of AF ablation is the occurrence of atrial tachycardias, with an incidence that is related to the type of ablation strategy implemented and the extent of the lesions created.⁶⁻¹¹ The pathophysiology of tachycardias following AF ablation can be classified into three categories: focal tachycardias, micro-reentry tachycardias due to localized reentries and macro-reentry tachycardias.¹²

Atrial tachycardias after AF ablation are resistant to antiarrhythmic management and are frequently more symptomatic than AF, mainly because of their faster ventricular rate.¹³ Therefore, ablation is frequently the only option for curative treatment. In the present paper, we describe a practical, systematic, 10-step approach to the diagnosis and ablation of these “iatrogenic” arrhythmias.

Step 1: Evaluate the P-wave morphology during tachycardia

The morphology of the 12-lead electrocardiogram (ECG) may prove helpful for the delineation of the underlying tachycardia

mechanism. In the case of pulmonary vein (PV) tachycardia, the P-wave morphology may facilitate the identification of the culprit PV (Figure 1).¹⁴⁻¹⁷ Surface ECG characteristics indicative of certain PV origin are presented in Figure 2. In the case of macro-reentrant tachycardia the ECG interpretation is more challenging, because prior left atrial ablation may divert the depolarization wavefront and decrease the predictive accuracy of the tachycardia’s P-wave morphology.¹⁸

Step 2: Evaluate the coronary sinus activation pattern

A proximal-to-distal activation pattern is associated with right atrial tachycardias, with tachycardias originating from the septal part of the left atrium (septum and right pulmonary veins), and with counterclockwise perimitral flutters. Distal-to-proximal activation of the coronary sinus is almost always indicative of a left atrial tachycardia. The percentage of tachycardia cycle length covered by the coronary sinus activation should also be taken into consideration. An almost simultaneous activation of the coronary sinus strongly disfavors perimitral flutter, but is frequently encountered in roof-dependent macro-reentrant tachycardias.

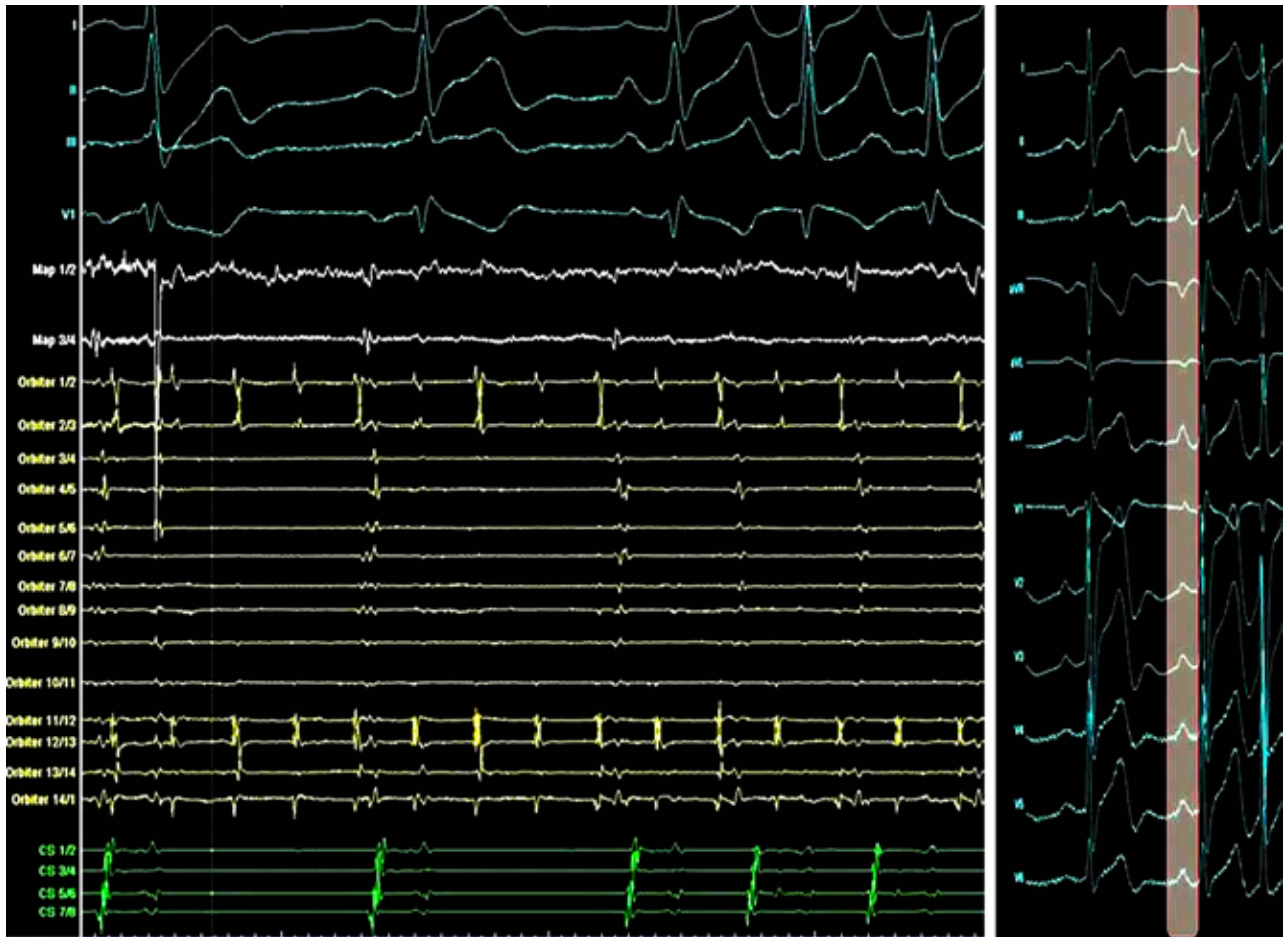


Figure 1. Left atrial tachycardia due to reconnection of the right superior pulmonary vein (RSPV). A circular multipolar catheter is located at the ostium of the RSPV (orbiter 1/2 to orbiter 14/1). The RSPV is isolated, as evidenced by an ongoing PV tachycardia recorded in the circular catheter and not conducted to the left atrium (PV exit block) during sinus rhythm. The third atrial depolarization denotes the initiation of an atrial tachycardia due to 2:1 reconnection of the RSPV. The morphology of the P-wave in the 12-lead ECG (highlighted panel at the right side of the tracing) and a comparison with the preexisting sinus P-wave morphology indicates that the origin of the atrial tachycardia is from the RSPV (change in P-wave configuration in lead V_1 from +/- biphasic in sinus rhythm to monophasic positive in tachycardia, with positive P-waves in inferior leads and negative P-wave in aVR).

Step 3: Evaluate the regularity of the atrial tachycardia

The coronary sinus activation pattern may also serve for assessment of tachycardia regularity. Cycle length variability higher than 15% is consistent with focal tachycardia. Conversely, tachycardias with a stable cycle length (variability <15%) may be either focal or reentrant.¹²

Step 4: Exclude a right-sided origin of the tachycardia

Gaining access to the left atrium with transeptal catheterization may occasionally prove challenging and is not always devoid of complications.¹⁹ The left atrium

should be mapped only after tachycardia originating from the right atrium has been ruled out. The cavotricuspid isthmus (CTI) should be the first site for entrainment mapping, irrespective of the surface ECG. CTI-dependent flutters following AF ablation may present atypical ECG features, occasionally differing markedly from the classical sawtooth pattern.²⁰ Therefore, the possibility of a CTI-dependent macro-reentry should not be excluded solely on the basis of 12-lead ECG morphology.²⁰ Negative entrainment at the CTI and at the high right atrium, especially if accompanied by a long post-pacing interval, practically rules out right atrial macro-reentrant circuits (Figure 3).²¹

Step 5: Perform entrainment from the proximal and distal coronary sinus

Positive entrainment in both the proximal and distal coronary sinus is strongly suggestive of a perimitral macro-reentry. Thereafter, transeptal catheterization is performed and entrainment is also attempted at the anterior mitral annulus; if positive, it validates the diagnosis of perimitral flutter.²² Alternatively, local activation time can be ascertained in relation to coronary sinus activation. If local activation at the anterior mitral annulus follows coronary sinus activation in a circumferential pattern then perimitral flutter is confirmed, whereas if both sites are activated simultaneously perimitral macro-reentry is ruled out. Perimitral flutter can be terminated with deployment of a mitral isthmus line connecting the posterolateral mitral annulus with the left inferior PV.²² Alternatively, a modified anterior line, connecting the ostium of the left superior PV to the anterolateral mitral annulus has also been shown to be feasible, safe and effective for the termination of perimitral flutter.²³

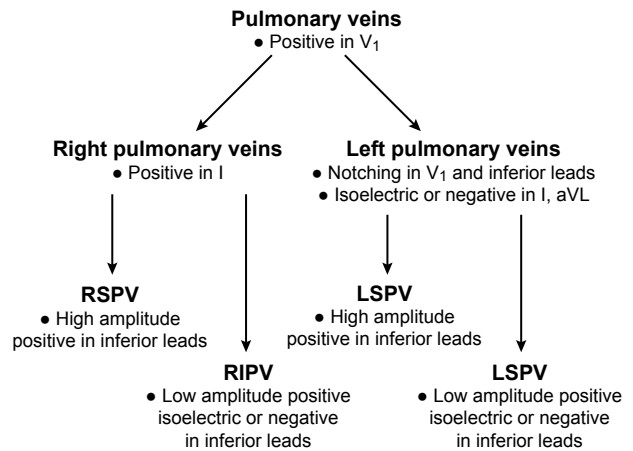


Figure 2. P-wave characteristics in tachycardias originating from pulmonary veins.

Step 6: Check the pulmonary veins for potential reconnection

All PVs should be checked for potential reconnection. A circular catheter is placed in all PVs to exclude recovery of conduction and facilitate reisolation. If the elec-



Figure 3. Negative entrainment maneuver. Entrainment maneuver during a regular atrial tachycardia (cycle length 290 ms) with distal-to-proximal activation in the coronary sinus (CS1/2: distal electrode, CS7/8: proximal electrode). Entrainment is performed from the distal electrode of a multipolar catheter (Halo1/2) situated at the lateral cavotricuspid isthmus. The return cycle exceeds by far the tachycardia cycle length (post-pacing interval [PPI] minus tachycardia cycle length [TCL] = 262 ms), indicating a long distance between the mapping electrode and the reentrant circuit. The considerably long value of PPI-TCL in combination with the distal-to-proximal activation pattern in the coronary sinus supports the left atrial origin of the tachycardia.

trical activity at the PV ostium or distally in the vein is faster than the rate of the tachycardia in the left atrium, the index vein is likely to be the origin of the tachycardia (Figure 4). The next step is to isolate the vein, which may result either in termination of the tachycardia or occasionally in restoration of sinus rhythm with an ongoing dissociated tachycardia in the PV.

Step 7: Perform entrainment from anterior and posterior left atrial wall

After having excluded perimitral flutter and PV reconnection, a peri-roof dependent macro-reentry should be ruled out, either with entrainment maneuvers or with evaluation of the activation pattern at the anterior and posterior left atrial wall. Consistently positive entrainment at the anterior and posterior left atrial wall indicates a roof-dependent flutter. Activation of the anterior and posterior left atrial wall in opposite directions is consistent with roof-dependent macro-reentry.¹² In such cases, a roof line should be deployed, connecting the

right and the left superior PV, and achievement of bidirectional block should be confirmed.²⁴

Step 8: Set window of interest for three-dimensional activation map

Although the mechanism and origin of atrial tachycardias following AF ablation can be identified conventionally, the use of three-dimensional contact mapping systems (e.g. CARTO, Biosense Webster, or NavX, St. Jude Medical) may prove helpful, especially in cases with complex anatomy. The key factor for optimal activation mapping is the proper selection of the duration and onset of the window of interest. The selected window should equal 90% to 95% of the tachycardia cycle length. In the case of macro-reentrant tachycardias the activation map covers the entire tachycardia cycle length and presents a characteristic “head meets tail” area (Figure 5). Setting the onset of the window of interest in relation to the reference electrogram does not change the circuit *per se*,

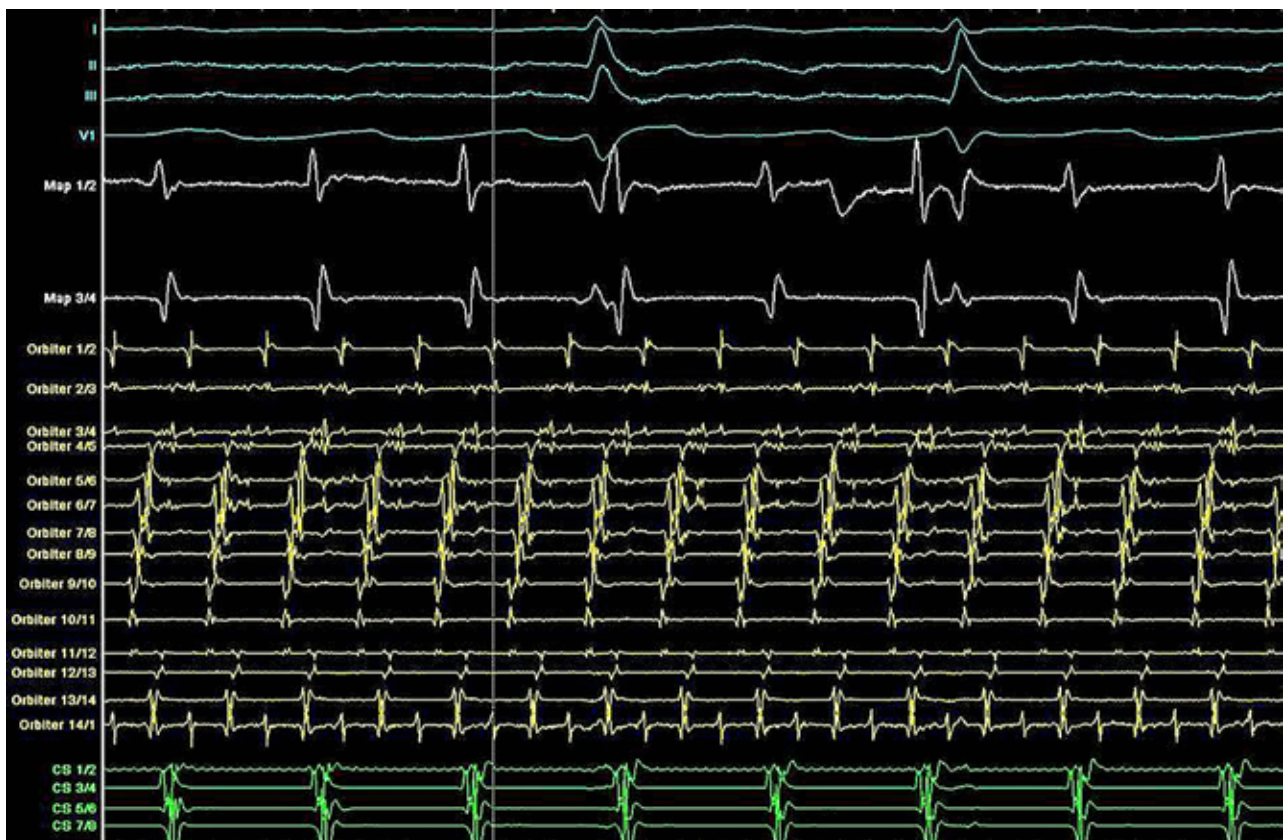


Figure 4. Pulmonary vein tachycardia. Atrial tachycardia after AF ablation originating from the right inferior pulmonary vein (RIPV). A multipolar catheter located at the ostium of the RIPV identifies a PV tachycardia with a faster rate than the atrial tachycardia recorded in the coronary sinus.

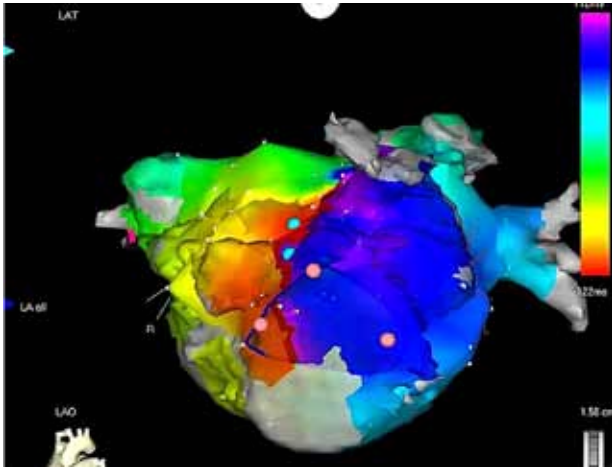


Figure 5. Perimitral flutter. Three-dimensional map of left atrial activation during atrial tachycardia with integrated anatomy after segmentation from a CT scan (available from previous atrial fibrillation ablation). The color-coded activation map demarcates a perimitral macro-reentry with an early-meets-late zone (red-violet line).

but shifts the “early meets late” zone around the circuit. The onset of the window of interest should be set halfway between two consecutive P-waves. In this way, the “head meets tail” zone coincides with the slow-conduction part of the circuit, based on the concept that slow atrial depolarization contributes minimally to P-wave morphology. This slow conduction mid-diastolic isthmus has been reported to be critical for maintaining the reentry circuit and therefore represents a target site for ablation.²⁵

Step 9: Construct activation map and tag points of interest

During construction of an activation map with the use of electroanatomic mapping systems, the operator should critically ascertain the color-coded activation sequence in conjunction with the morphology and relative timing of local electrograms. Accurate allocation of the onset of local activation time may be challenging in areas displaying fragmented, low-voltage electrograms and minor differences may have considerable impact on the color-coded map. In similar cases, these spots may be tagged anatomically without necessarily incorporating them in the activation map. Electrically silent areas and sites with widely split potentials should also be labeled in order to elucidate the sequence of activation. The main concept is to determine whether the wavefront propagation of the index tachycardia is reentrant or centrifugal. In the case of a reentrant circuit not compatible with the above-

mentioned macro-reentries (perimitral, roof-dependent or CTI-dependent), an ablation line is deployed in order to transect the reentrant circuit at the critical isthmus of slow conduction (see previous step) and is extended to reach anatomic boundaries or areas of electrical silence. In the case of centrifugal activation, the aim is to identify the point or area with the most premature activation.

Step 10: Search for target site meeting ablation criteria when map shows centrifugal activation

In the context of prior left atrial ablation for substrate modification, the earliest activation may be confined to one spot (focal origin), or may be present throughout a broader area (localized micro-reentry) with subsequent centrifugal spread of the depolarization to the rest of the atrium. Conceptually, the site of earliest activation represents the target for ablation. In the case of a rather wide area of prematurity, it would be plausible to proceed with detailed mapping of the early activation site, aiming to identify a target spot satisfying one or more of the following electrophysiologic criteria: a) a highly fragmented, long duration, low voltage electrogram; b) positive entrainment; and c) a gradient of activation between the proximal and distal bipole of the mapping catheter, denoting confinement of the circuit to the visited area (Figure 6). Ablation of spots meeting the abovementioned prerequisites has been associated with tachycardia termination.¹²

Conclusion

Management of atrial tachycardias after AF ablation requires a systematic strategy. Clues regarding the tachycardia mechanism can be derived from the morphology of the surface P-wave, the tachycardia cycle length variability, the coronary sinus activation pattern, as well as by electroanatomical mapping and entrainment maneuvers. Careful synthesis of the information provided by these tools facilitates delineation of the underlying mechanism and decision making about ablative treatment. The proposed stepwise approach, although not able to recapitulate all available options, may serve as a guide to the diagnostic approach and ablation of atrial tachycardias following AF ablation.

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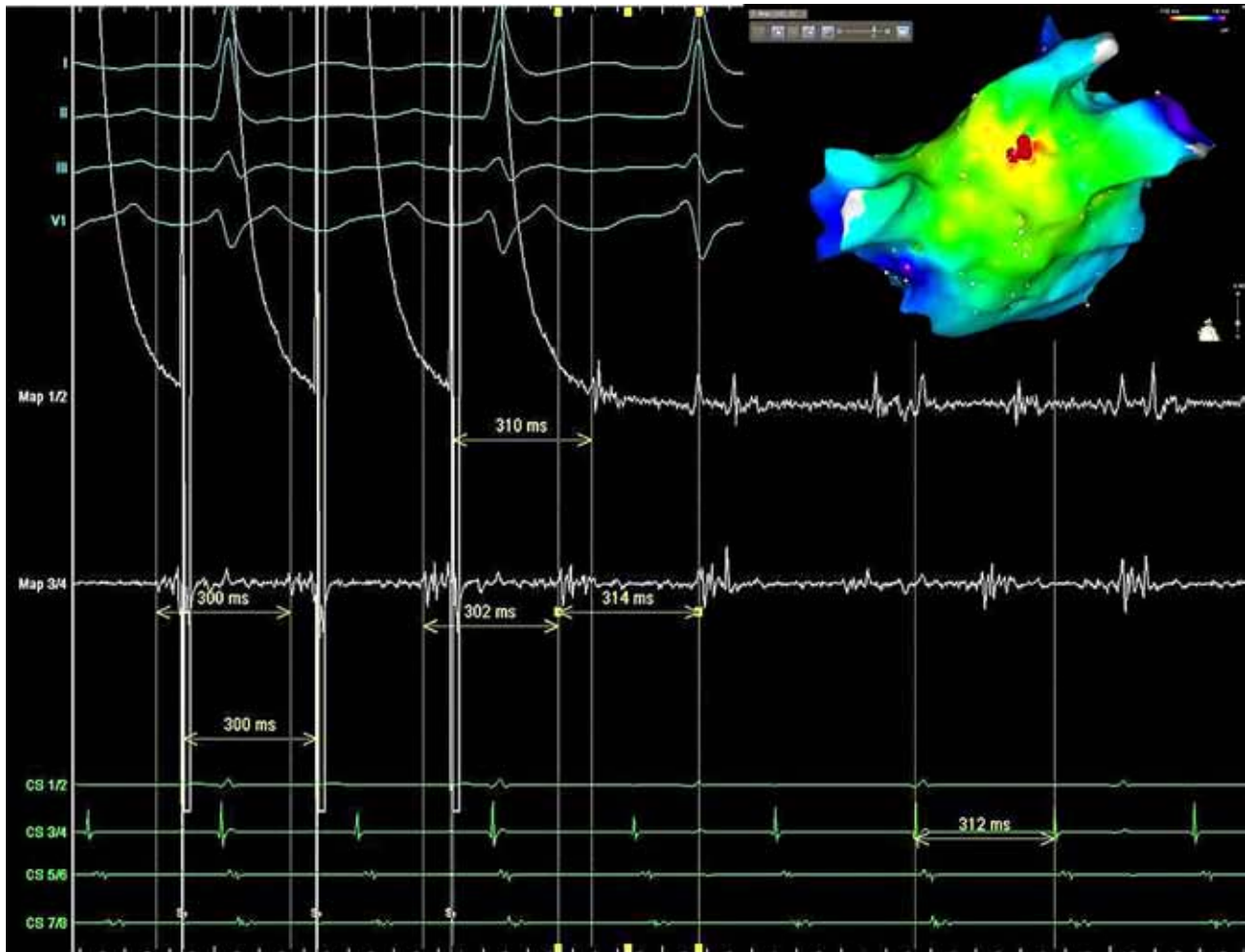


Figure 6. Micro-reentrant atrial tachycardia. The tachycardia has a cycle length of 312 ms with a distal-to-proximal activation sequence in the coronary sinus. Entrainment from the coronary sinus was negative. A check of the pulmonary veins revealed no reconnection. Entrainment from the anterior and posterior left atrial wall was not consistent with roof-dependent macro-reentry. Activation mapping of the tachycardia was performed with CARTO 3 (right upper corner of the figure) and revealed centrifugal activation of the left atrium. In the area of earliest activation, a site with a fragmented potential covering a considerable percentage of the cycle length was found. Pacing slightly faster than the tachycardia cycle length resulted in positive tachycardia entrainment (post-pacing interval \approx tachycardia cycle length). Ablation at this site resulted in termination of the tachycardia.

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