A case report of successful treatment of longstanding persistent atrial fibrillation with ablation for fractionated potential with conduction delay during rapid pacing

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Introduction

Atrial fibrillation (AF) is the most common cardiac arrhythmia, with an increased risk for mortality.[1] Fractionated electrograms characterized by slow conduction have been observed in the myocardial sleeves of the pulmonary veins (PVs),[2] and ectopic beats with a very short cycle length from the PVs provoked paroxysmal AF.[3] Given that they induce and maintain micro-reentry, which is the mechanism of AF, the current standard treatment strategy for AF ablation is pulmonary vein isolation (PVI). However, AF promotes atrial fibrosis, which is thought to play an important role in AF formation and maintenance.[4] The role of PV in maintaining AF becomes less as AF continues,[5] and PVI becomes insufficient for treating patients with persistent and longstanding persistent AF. Furthermore, substrate ablation in the atrium may terminate AF without PVI.[5] Linear ablation, complex fractionated atrial electrogram ablation,[6] left posterior wall isolation,[7] low-voltage area ablation,[8] fractionated signal area in the atrial muscle ablation,[9] and so on have been reported, but their effects are still controversial. We considered that the AF substrate, which is similar to PV, is formed in the atrial muscle, and that we might treat longstanding persistent AF if we are able identify the affected area. We report a case of successful treatment for longstanding persistent AF by ablating for fractionated potential with conduction delay during rapid pacing in the atrial muscle, which approximates the electrogram characteristics of PV and the superior vena cava (SVC), triggering paroxysmal AF.

KEYWORDS Fractionated potential; Conduction delay; Rapid pacing; Longstanding persistent atrial fibrillation; Catheter ablation
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KEY TEACHING POINTS

- Atrial fibrillation (AF) promotes atrial fibrosis, which is thought to play an important role in AF formation and maintenance.
- A short coupling interval stimulus prolongs the pulmonary vein and atrial conduction time, which is correlated to AF vulnerability and recurrence.
- A fractionated potential with conduction delay during rapid pacing in the atrium might be the origin and substrate of longstanding AF.

Case report

We observed the electrograms of patients with spontaneous paroxysmal AF. We sometimes have experienced cases of AF termination simultaneously with the completion of PVI even if fibrillation is sustained in the PV (Figure 1A). Figure 2B shows the start of AF from the left superior PV (LSPV). The ectopic beat that occurred in the LSPV with a coupling interval of 157 ms did not induce AF but that with a coupling interval of 139 ms induced AF with fractionated potential. These data indicate that PV is not only a trigger but a substrate of paroxysmal AF. Figure 1C shows a case of AF with an SVC trigger. The ring catheter was in the right atrial septum and the high-density mapping catheter (Advisor HD Grid Mapping Catheter, Sensor Enabled; Abbott, Chicago, IL) was located in the SVC (Figure 1E). The Advisor HD Grid recorded the ectopic beats that were the AF origins. These electrograms demonstrated that the ectopic beats were repeated with short coupling intervals and prolonged and increased the fractionated potential. The earliest electrogram observed in spontaneous ectopic beat was HD Grid A 1-2, and we stimulated the area with a cycle length of 240 ms (Figure 1D). The first stimulation made the electrogram of the SVC, which showed a fractionated potential with conduction delay than in sinus beat; the subsequent

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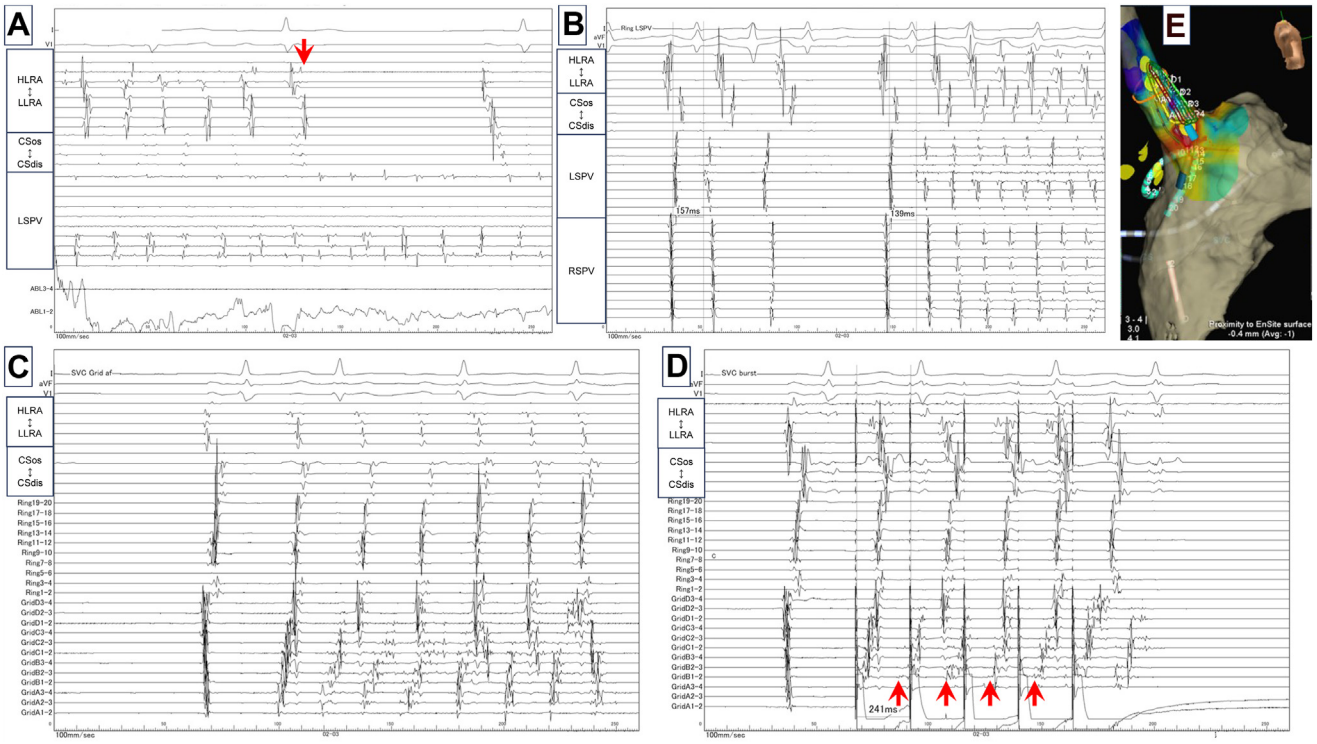

Figure 1 A trigger and substrate of atrial fibrillation (AF) in the pulmonary vein (PV) and superior vena cava (SVC). AF termination simultaneously with the completion of PV isolation (PVI) may occur even if fibrillation is sustained in the PV. The red arrow is the time of PVI completion. **A:** The start of AF from the left superior pulmonary vein (LSPV). The ectopic beat that occurred in the LSPV with a coupling interval of 157 ms did not induce AF, but that with a coupling interval of 139 ms induced AF with a fractionated potential. **B:** AF from the SVC trigger. The electrograms demonstrated that the ectopic beats were repeated with short coupling intervals and prolonged and increased fractionated potential with conduction delay. **C:** The SVC electrogram stimulated by using the Advisor HD Grid A 1-2 (Abbott, Chicago, IL) with a cycle length of 240 ms. The first stimulation made the electrogram of the SVC, which showed a fractionated potential with conduction delay than in sinus beat; the subsequent electrograms of SVC were observed before the successive stimulation. **D:** The location of the Advisor HD Grid and ring catheter in the right atrium.

electrograms of the SVC were observed before the successive stimulation. We considered the micro-reentry in the SVC as a substrate of ectopic beats and AF.

Figure 2 shows an electrogram of another patient. In this patient, AF started from an ectopic beat from the right superior PV (RSPV) (Figure 2A). After PVI, we located the ring catheter in the RSPV distal and Advisor HD Grid in the RSPV proximal (Figure 2E). We stimulated the RSPV using the ring catheter by coupling intervals of 300 (Figure 2B), 260 (Figure 2C), and 220 ms (Figure 2D). The red arrows in both directions represent the duration of the fractionated potential with conduction delay induced by the stimulus. The shorter the coupling interval we stimulated, the more the electrogram in the PV showed a fractionated potential with conduction delay. Especially when stimulated by 220 ms, the electrocardiogram appeared significantly prolonged and fractionated, with decreased voltage height. We considered that these electrophysiological characteristics were micro-reentry associated with the origin and substrate of AF, and this characteristic was thought to form in the atrial muscle of cases with longstanding persistent AF.

In a 74-year-old man with longstanding persistent AF with an unknown history of morbidity, the left atrial diameter was 50 mm by ultrasound cardiography. We performed PVI and administered 100 mg bepridil, 40 mg aprindine, and 2.5 mg bisoprolol. AF had recurred 2 weeks later; thus, 5 months later, we performed roof and anterior linear ablation, low-voltage area ablation, complex fractionated atrial electrogram ablation, and fractionated signal area in the atrial muscle ablation using the ENSITE NavX mapping system (Abbott, Chicago, IL) and non-PV foci ablation provoked by isoproterenol and adenosine triphosphatase. After the second catheter ablation, we administered the same drugs. AF still recurred 2 weeks later, and defibrillation after a blanking period was ineffective. In the third catheter ablation, performed after 7 months of second catheter ablation, we explored the entire atrial electrogram while stimulating the atrium rapidly with the mapping catheter located in the coronary sinus. Figure 3A shows a representative normal electrogram. During rapid pacing, the electrogram on the Advisor HD Grid is spiky, with high voltage and less fractionation. Conversely, Figure 3B shows an abnormal electrogram. Rapid pacing induced a fractionated potential with conduction delay and a decrease in voltage height, which may cause premature supraventricular contraction after pacing and lead to AF maintenance. We identified these regions and ablated them with a lesion index of 5 using a TactiCath Contact Force Catheter, Sensor Enabled (Abbott, Chicago, IL). Figure 3C is

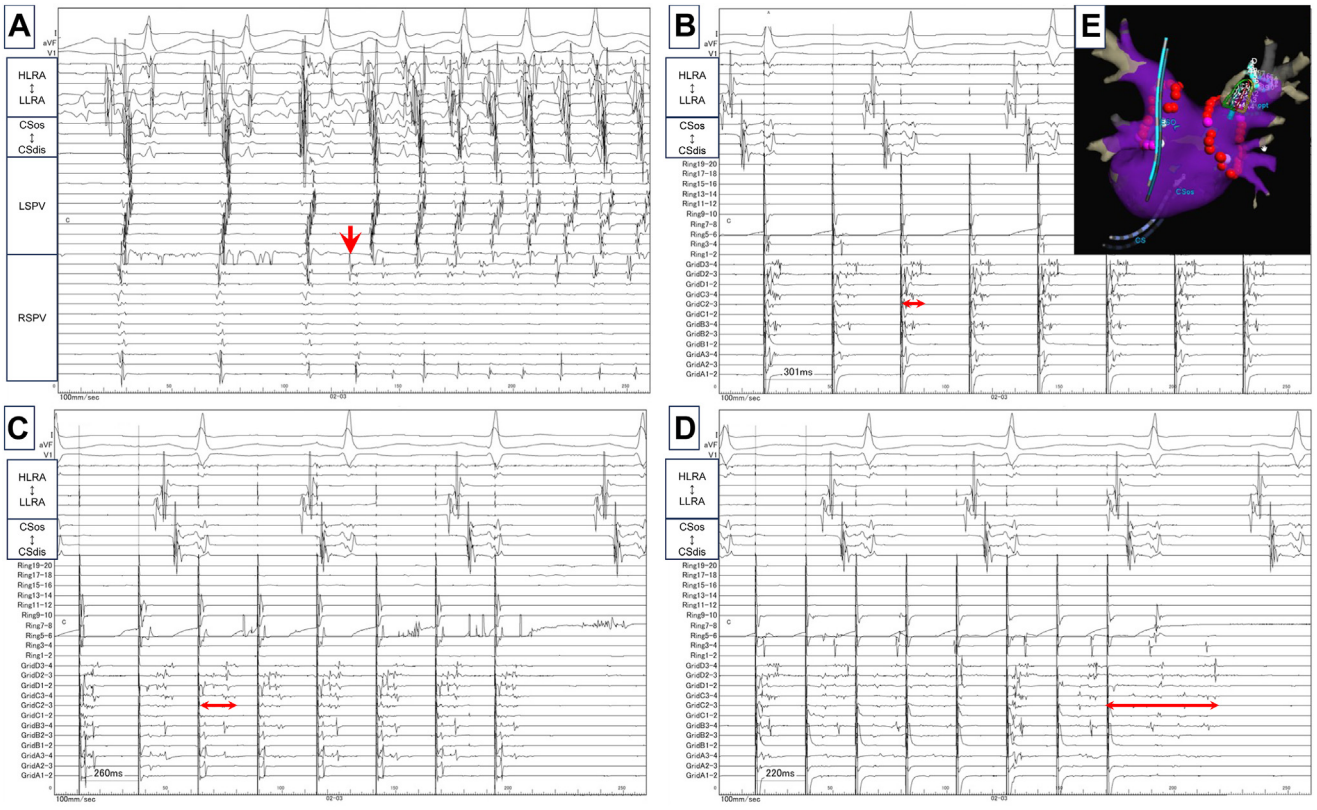

Figure 2 Electrogram characteristics provoking atrial fibrillation (AF) in the right superior pulmonary vein (RSPV). **A:** The start of AF from the RSPV. The red arrow is the ectopic beat that induces AF. **B:** The electrogram showing the stimulation of the RSPV using the ring catheter by coupling intervals of 300 ms. The red arrows in both directions represent the duration of the fractionated potential with conduction delay induced by the stimulus (**B–D**). **C:** The electrogram showing the stimulation of the RSPV using the ring catheter by coupling intervals of 260 ms. **D:** The electrogram showing the stimulation of the RSPV using the ring catheter by coupling intervals of 220 ms. **E:** The location of the Advisor HD Grid (Abbott, Chicago, IL) and ring catheter in the RSPV.

the voltage map before ablation, and the red, pink, and white tags are ablation points. The red tag has a lesion index of >5, the pink tag is between 5 and 4.5, and the white tag is <4.5. In the voltage map, the area over 0.5 mV is shown in purple, and that under 0.1 mV is in gray. The fractionated potential with conduction delay was found in the gray area. Before ablation, as a pacing cycle length of 260 ms induced AF, we mainly stimulated the atrium by using a pacing cycle length of 280 ms. After ablation, AF could not be induced up to a pacing cycle length of 180 ms. After the third catheter ablation, a normal sinus rhythm was maintained for more than 1 year using the same pharmaceuticals.

Discussion

We considered that the electrogram characteristics in the atrial muscle, which are similar to those of the PV electrogram that provokes AF, are the substrate of longstanding persistent AF, and we succeeded in treating longstanding persistent AF by ablating the area with the electrogram characteristics. We presented the fractionated potential with conduction delay during rapid pacing in the PV and atrial muscle. The AF mechanism is micro-reentry, which is electrophysiologically expressed in fractionated potential. The AF-triggered ectopy from the PV has a short coupling interval and shows a fractionated potential in an electrogram[10]; a single stimulus mimicking the ectopic beat in the PV prolongs the intra-PV conduction time and induces AF.[11] These reports indicate that similar reactions as spontaneous ectopic beats occur in stimuli. Additionally, a conduction delay in the atrium by stimulating the short coupling intervals is correlated with AF vulnerability and recurrence.[12] We usually induce AF by rapid pacing; however, in our case, we observed the electrogram in the whole atrium and confirmed the fractionated potential with conduction delay transitioned to AF. Given that the inducibility of AF changes depending on the location of the premature atrial contraction (PAC),[13] we might need to confirm the electrogram by pacing the atrial muscle at some points. After the ablation of these areas, AF by rapid pacing is less likely to occur. AF noninducibility by rapid pacing is reported to be associated with a reduced clinical recurrence of AF.[14]

Regarding AF recurrence, no difference was observed between cases with and without non-PV PAC after PVI.[15] This indicates that the substrate of AF, not PAC, is important in the occurrence of AF; hence, in such a case, the ablation of the area is reasonable. We consider that ectopic beats induce micro-reentry, and micro-reentry induces micro-reentry and AF maintenance. A fractionated potential with conduction delay during rapid pacing might be associated with the origin and substrate of longstanding persistent AF.

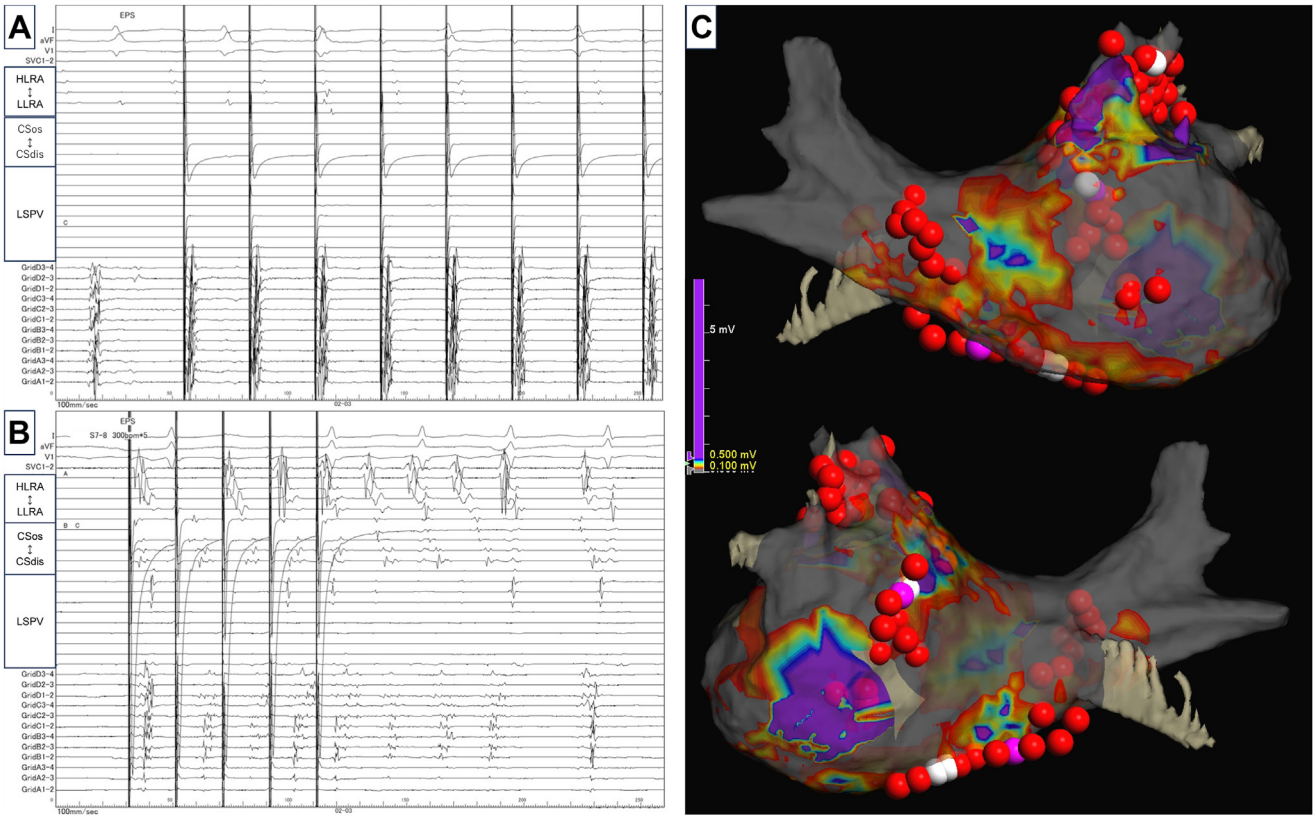

Figure 3 Normal and abnormal electrograms during rapid pacing in the atrial muscle. **A:** A normal electrogram on the Advisor HD Grid (Abbott, Chicago, IL) during rapid pacing, which shows a spiky appearance with high voltage and less fractionation. **B:** An abnormal electrogram on the Advisor HD Grid during rapid pacing, which shows a fractionated potential with conduction delay and low voltage. **C:** The voltage map before ablation with the red, pink, and white tags as the ablation points.

We reported the possibility that fractionated potential with conduction delay during rapid pacing is associated with AF occurrence and maintenance. We exclusively stimulated the atrial muscle using the mapping catheter in the coronary sinus. It is necessary to assess whether stimulation from other areas of the atrial muscle is needed. In addition, it is essential to investigate whether this strategy is effective for other patients with refractory AF.

Conclusion

A fractionated potential with conduction delay during rapid pacing in the atrium might be the origin and substrate of longstanding persistent AF. To the best of our knowledge, this is the first case report of successful treatment targeting the electrogram transition to AF.

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Ethical consideration

The work was carried out in accordance with the Declaration of Helsinki. Informed consent for participation and publication was received from the participant.

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