A case of ventricular tachycardia with an intramural excitable substrate detected by evaluating the close and the wide bipolar electrograms of a linear decapolar catheter

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Introduction

Although reentrant ventricular tachycardia (VT) has been reported to have a 3-dimensional circuit within the ventricular myocardium,[1] the epicardial side potentials cannot be assessed without epicardial mapping, which requires an invasive procedure. Bipolar electrogram recordings have been widely used to assess the near-field substrate, while unipolar electrogram recordings are thought to evaluate the myocardium in the far field (including the intramural and epicardial sides).

We herein report a case in which we confirmed that part of the circuit of a VT existed in the intramyocardium by evaluating the bipolar potentials recorded with 2 different electrode spacings.

Case report

The patient was a 68-year-old man who had been diagnosed with dilated cardiomyopathy for 6 years and had been an outpatient. He was prescribed beta-blockers, angiotensin-converting enzyme inhibitors, spironolactone, and diuretics. The patient developed sudden palpitations and respiratory distress during the night and was transferred to our hospital the next morning after calling for an ambulance. At the time of presentation, he had VT with a heart rate of 120 beats per minute. Since he was in congestive heart failure, electrical cardioversion was performed to convert him to sinus rhythm.

KEYWORDS Ventricular tachycardia; Intramural excitable substrate; Wide bipolar electrogram; Close bipolar electrogram; Linear decapolar catheter

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KEY TEACHING POINTS

- If there is a missing zone in the continuity of excitation when performing high-density mapping with a 3D mapping system, a 3D ventricular tachycardia circuit should be considered.
- When mapping with a linear decapolar catheter (1-mm electrode size and 2-8-2-mm interelectrode spacing), conventional close bipolar and wide bipolar potentials can be recorded simultaneously. By recording both close bipolar and wide bipolar potentials, we can observe where the catheter is in contact with the myocardium without gaps.
- Wide bipolar potentials can be a tool for evaluating the depth of the subendocardial area that can be treated with radiofrequency catheter ablation from the endocardial side.

Subsequently, the heart failure was controlled, and catheter ablation was performed on the eighth day after admission.

First, left ventricular angiography showed an aneurysmal formation in the region of the lower wall of the left ventricular septum (Supplemental Video 1). Mapping in the left ventricle was performed using a DECANAV catheter (Biosense Webster, Diamond Bar, CA). The catheter was used via the retrograde aortic approach for mapping the left ventricle during sinus rhythm. Mapping during sinus rhythm revealed delayed potentials in the posteroseptal region, which might have been an arrhythmogenic substrate (Figure 1A and Supplemental Video 2). Intracardiac echocardiography of the same region showed increased brightness compared to the surrounding area, suggesting advanced fibrosis. After induction with continuous stimulation (400 ms) from a mapping

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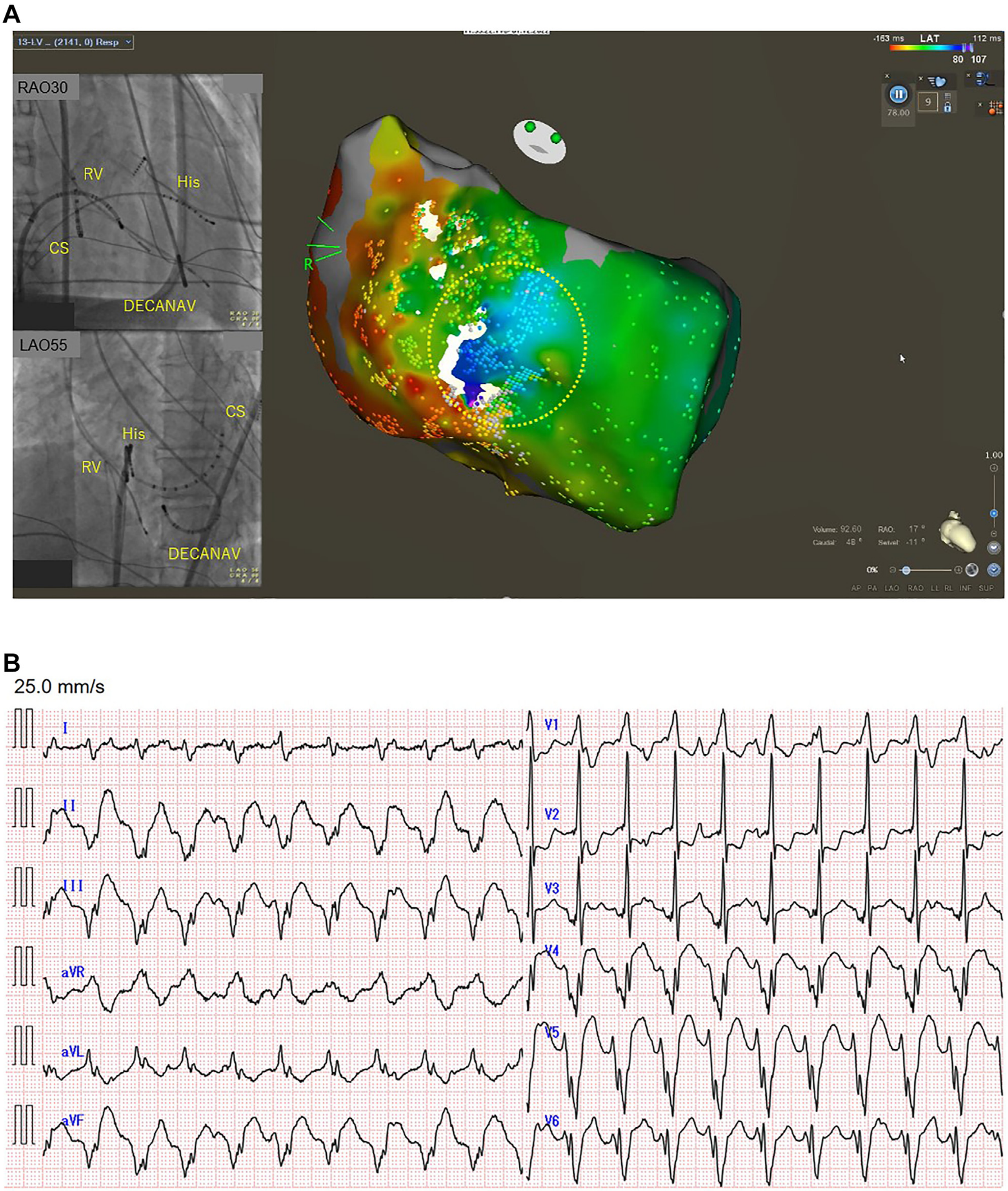

Figure 1 **A:** Location of the catheters on fluoroscopy and the activation map during sinus rhythm. Left ventriculography revealed an aneurysm in the inferior septal region. Initially, mapping during sinus rhythm was performed using a linear decapolar catheter. Delayed potentials were observed around the area where the ventricular aneurysm existed, and it was thought that it might be an arrhythmogenic substrate. **B:** Findings on a 12-lead electrocardiogram (ECG) during ventricular tachycardia. The 12-lead ECG showed right bundle branch block, left-axis deviation, wide QRS tachycardia, atrioventricular dissociation, and atrioventricular dissociation.

catheter, the clinical VT was induced (tachycardia cycle: 470 ms) (Figure 1B).

The hemodynamics were stable, so mapping was performed using the DECANAV. The propagation map and voltage map obtained from the mapping are shown in Figure 2A and 2B. A figure-of-8 reentrant circuit was considered, with an isthmus around the area where delayed potentials were detected during sinus rhythm, but there was no

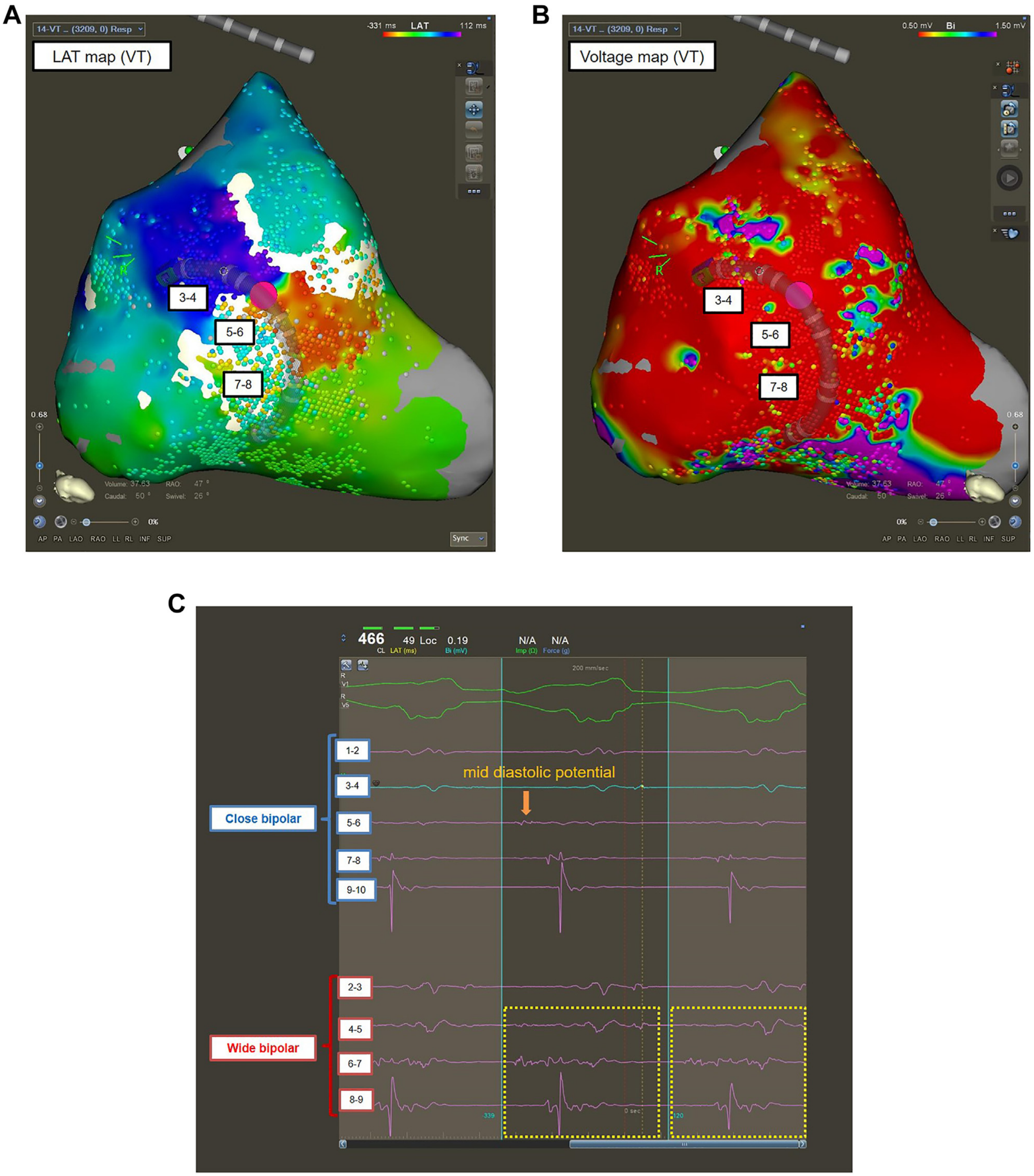

Figure 2 **A–C:** Shown from left to right: local activation time (LAT) map during ventricular tachycardia (VT); bipolar voltage map during VT; intracardiac potentials recorded by the linear decapolar catheter. (A) and (B) show the location of the decapolar catheter when the potential shown in (C) was acquired, indicated by the shadow and pink tag as a landmark where the blue and red are adjacent to each other in the LAT map. **A:** A possible figure-of-8 circuit was seen with an isthmus around the delayed potential in Figure 1A; however, there was no continuous excitation propagation between the blue and red areas, and a missing zone of around 30 ms was observed. **B:** A broad low-voltage area was observed, indicating that the VT appeared within this area. **C:** Bipolar potentials recorded with a wide bipolar electrode spacing during VT exhibited long-duration potentials. Bipolar potentials recorded with a narrow electrode spacing, such as those recorded by electrode pair 3–4, recorded diastolic potentials that were flat until the QRS phase, whereas the potentials recorded by a wide bipolar electrode spacing, such as by 4–5 and 6–7, recorded fragmented potentials from the diastolic potentials to the QRS phase.

continuous excitation propagation between the purple and red, and a missing zone of about 30 ms was observed (Figure 2A).

A mapping catheter was placed in the area where the delayed potentials were observed during sinus rhythm, and the potentials were evaluated in detail (Figure 2C). The

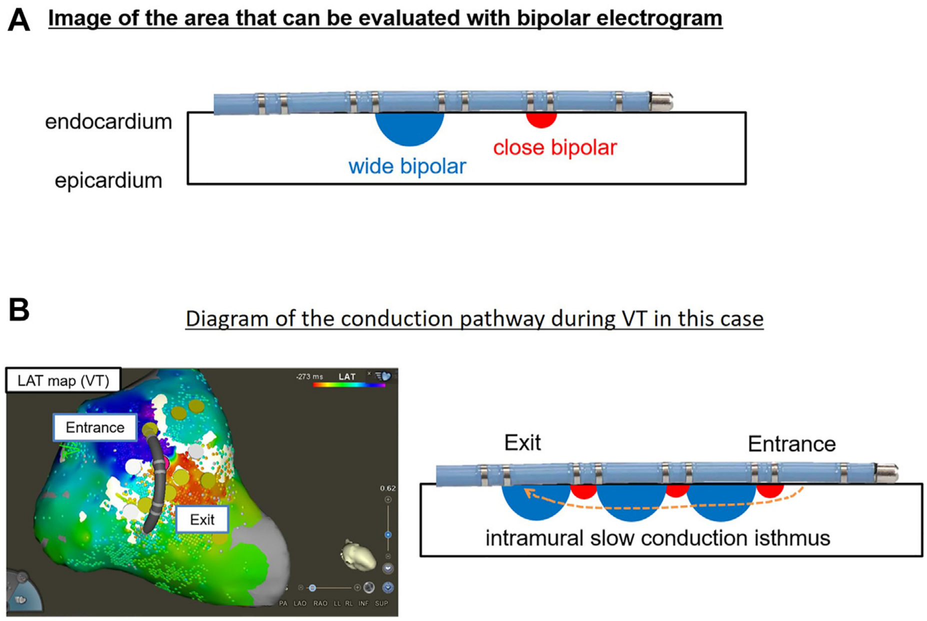

Figure 3 **A:** Image of the potentials recorded by a wide bipolar electrode spacing. The wide bipolar recordings have a relatively wide distance between the electrodes, which may allow the collection of information in not only the horizontal direction but also deeper regions. **B:** Illustration of the conduction at the isthmus site of the ventricular tachycardia as assumed in this case: the slow conduction isthmus passed through an intramural region, so it was possible to record continuous potentials only with wide bipolar spaced electrodes.

results showed that only the wide bipolar potentials recorded had a long duration (around 200 ms). As shown in Figure 2C, diastolic potentials were recorded with a narrow bipolar electrode, spacing such as DECA 3–4, which were flat until the QRS phase; in contrast, with a wide bipolar electrode spacing such as DECA 4–5 and DECA 6–7, the diastolic potentials continued from the diastolic potential to the QRS phase. We achieved concealed entrainment at a site within the isthmus, and the postpacing interval matched the cycle length of the VT (Supplemental Figure 1). The activation map and electrophysiology studies showed that long-duration potentials were recorded only in a wide bipolar region in the area considered to be the central isthmus, suggesting that part of the VT circuit might have existed in the intramural region.

The critical isthmus was considered to be in the intramural area and was ablated with a transaorta and transseptal approach at 35–40 W for 1–2 minutes or longer using a ThermoCool SmartTouch SF (Biosense Webster). The ablation resulted in the disappearance of the delayed potentials, and the VT was no longer inducible, so the procedure was terminated (Supplemental Figure 2). Subsequently, a cardiac resynchronization therapy defibrillator (CRT-D) (Cobalt MRI CRT-D; Medtronic Inc, Minneapolis, MN) implantation was performed on the 14th day, and the patient was discharged from the hospital on the 22nd day. Six months after the procedure, the CRT-D recorded that the patient was doing well, with no occurrence of VT and no worsening of his heart failure.

Discussion

In the present case, we were able to find and treat the VT circuit in the intramural region by mapping it with a linear decapolar (1-mm electrode size and 2-8-2-mm interelectrode spacing) catheter and evaluating the bipolar potentials with 2 different interelectrode spacings. To our knowledge, this is the first report of assessing an arrhythmogenic substrate deep in the myocardium by evaluating the bipolar potentials produced by 2 different interelectrode spacings with a linear decapolar catheter.

The evaluation of an arrhythmogenic substrate with different interelectrode spacings

In recent years, remarkable advances in 3D mapping systems have made it possible to acquire a very large number of bipolar potentials (thousands to tens of thousands of points) and visualize the mechanism of arrhythmias. In particular, 3D mapping systems are often used in the ablation of atrial arrhythmias, and since the atria have thinner walls than the ventricles, it is thought that the potentials recorded on the endocardial side with smaller electrodes and a narrower electrode spacing will lead to the evaluation of fine potentials,[2] and several multipolar electrode catheters for this purpose are also on the market.

However, in the treatment of VT, mapping only from the endocardial side is sometimes insufficient because of the wall thickness of the ventricular muscle, and it may be necessary to evaluate the epicardial potentials as well. Tung and colleagues[1] reported that the VT circuit extends 3-dimensionally in 73% of cases of ischemic heart disease and 49% of cases of nonischemic heart disease. In the treatment of VT, with respect to the evaluation of potentials, studies have found that the evaluation of bipolar and unipolar potentials can be used to assess the arrhythmogenic substrate region within the myocardium.[3–5]

Usefulness of mapping with a linear decapolar catheter

We believe that a linear decapolar catheter has several advantages for use in ventricular arrhythmias. First of all, it has been reported that bipolar potentials with a wide interelectrode spacing cover a large area, making it easier to detect abnormal potentials on the endocardial side. Naeemah and colleagues[6] reported that a wide bipolar spacing is able to record larger abnormal potentials in fascicular VT with arrhythmias originating from the superficial endocardial layer and described the usefulness of a linear decapolar catheter.

Second, there are features related to the depth that can be assumed from the configuration of the potentials. The bipolar potential is composed of unipolar potentials, and the difference between the unipolar potentials is expressed. Takigawa and colleagues[7] reported that although the far-field voltage systematically increases with increased an electrode spacing, near-field voltages are more variable, depending on the local surviving muscular bundles. Therefore, theoretically, the range that can be evaluated by bipolar potentials is considered to be the deep region depending on the distance between the electrodes, as shown in Figure 3A.

In the present case, close bipolar and wide bipolar electrode spacings were evaluated simultaneously, and conduction-delayed potentials were recorded only with the wide bipolar electrode spacings at a time phase corresponding to the missing zone in the activation map recorded on the endocardium. This suggested the existence of an intramural slow conduction isthmus connecting the entrance and exit, as shown in Figure 3B. While unipolar potentials can evaluate a wide area including on the epicardial side, they may contain noise owing to the far-field influence. A wide bipolar electrode spacing can be a tool for evaluating the depth of the subendocardial area that can be treated with radiofrequency catheter ablation from the endocardial side. Sahara and colleagues[5] reported that an Advisor™ HD Grid (Abbott Laboratories, Abbott Park, IL) catheter can be used to evaluate heterogeneous scars with functional block by assessing the bipolar potentials with different interelectrode spacings of 3 mm and 6 mm. The HD Grid catheter is specific to the EnSite system and cannot be used with the CARTO system. In the CARTO system, the DECANAV (1-mm electrode size and 2-8-2-mm interelectrode spacing) is used to evaluate the endocardial surface potentials with a close 2-mm bipolar spacing, while the midmyocardium potential can be evaluated with a wide 8-mm bipolar spacing (4 times the electrode spacing). The difference between the two may be more pronounced.

In ventricular mapping, not only close bipolar electrode spacing but also wide bipolar electrode spacing may allow for the estimation of the depth of the arrhythmogenic substrate.

Conclusion

In identifying the circuit of VT, evaluating the electrograms recorded by close and wide bipolar electrode spacings with a linear decapolar catheter allows for a 3-dimensional assessment.

Appendix

Supplementary Data

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.hrcr.2023.04.013.

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