Visualizing the critical isthmus of complex atrial tachycardia using a novel mapping technology of peak frequency duplicate – Initial clinical experience in 2 case reports

Koji Sudo, MD,* Kenji Kuroki, MD,* Tetsuya Asakawa, MD,† Chisa Asahina, MD,* Yuya Tanaka, MD,* Akira Sato, MD*

*From the *Department of Cardiovascular Medicine, University of Yamanashi, Yamanashi, Japan, and †Department of Cardiology, Yamanashi Kosei Hospital, Yamanashi, Japan.*

Introduction

High-density mapping in a 3D electroanatomical mapping system is an effective tool to determine a tachycardia circuit. Identifying the tachycardia circuit is essential in catheter ablation strategies. However, the tachycardia circuit in complex atrial tachycardias (ATs) remains challenging. Two pulmonary vein (PV) gaps related AT are associated with residual PV conduction gaps in previously ablated PV isolation lines.[1]

Omnipolar technology (OT) is a powerful mapping system that selects the best omniplar electrograms (EGMs) using a high-density grid mapping catheter (HDG mapping catheter; Abbott, Inc) with the EnSite X EP system (Abbott, Inc, Green Oaks, IL).[2] Previously, the traditional annotation of local electrogram timing involved selecting the peak amplitude or maximal dV/dT; however, local electrogram categorization based on the peak frequency was not possible. Furthermore, distinguishing near-field potentials from far-field potentials was challenging. The selection and annotation of the highest-frequency component of the local electrogram is now possible in a novel technology (EnSite OT Near Field [OTNF], EnSite X EP system; Abbott, Inc). Peak frequency duplicate is a novel algorithm that preferentially selects the point with the highest peak frequency for omnipolar EGMs in EnSite X version 3. Here, we demonstrate the utility of a novel software for generating peak frequency duplicate with EnSite X version 3 to visualize the critical isthmus and PV gaps in complex ATs and to determine the accurate ablation sites.

KEYWORDS Atrial tachycardia; Catheter ablation; Omnipolar technology near field; High-density mapping catheter; Peak frequency duplicate

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Address reprint requests and correspondence: Dr Kenji Kuroki, Department of Cardiovascular Medicine, University of Yamanashi, Shimokato 1110, Chuo, Yamanashi, 409-3898, Japan. E-mail address: kkuroki@yamanashi.ac.jp.

KEY TEACHING POINTS

- A novel algorithm using peak frequency duplicate with omnipolar technology (OT) Near Field can visualize exact locations of complex atrial tachycardia circuits and pulmonary vein (PV) gaps more effectively than OT certainty duplicate.
- The critical isthmus and PV gaps can be determined using an emphasis map as a combination of a local activation map and peak frequency maps with peak frequency duplicate, leading to successful ablation sites.
- For peak frequency duplicate, a threshold of 550 Hz could serve as a good cut-off value for detailed evaluation of complex tachycardia circuits and PV gaps.

Case report

Case 1

A 70-year-old male patient with a history of catheter ablation for atrial fibrillation (AF) was admitted to our hospital. Six months prior, the patient underwent extensive PV isolation and superior vena cava isolation for persistent AF. After a blanking period, AT with palpitations was documented at an outpatient clinic without antiarrhythmia drugs. Twelve-lead electrocardiogram (ECG) showed atrial tachycardia with a tachycardia cycle length (TCL) of 270 ms. Transthoracic echocardiography revealed a normal ejection fraction of 62% and no structural heart disease.

An electrophysiological study and catheter ablation were performed after obtaining informed consent. Coronary sinus (CS) venography revealed no Marshall vein and a 10-electrode catheter was placed in the CS. After transseptal puncture, high-density mapping during AT

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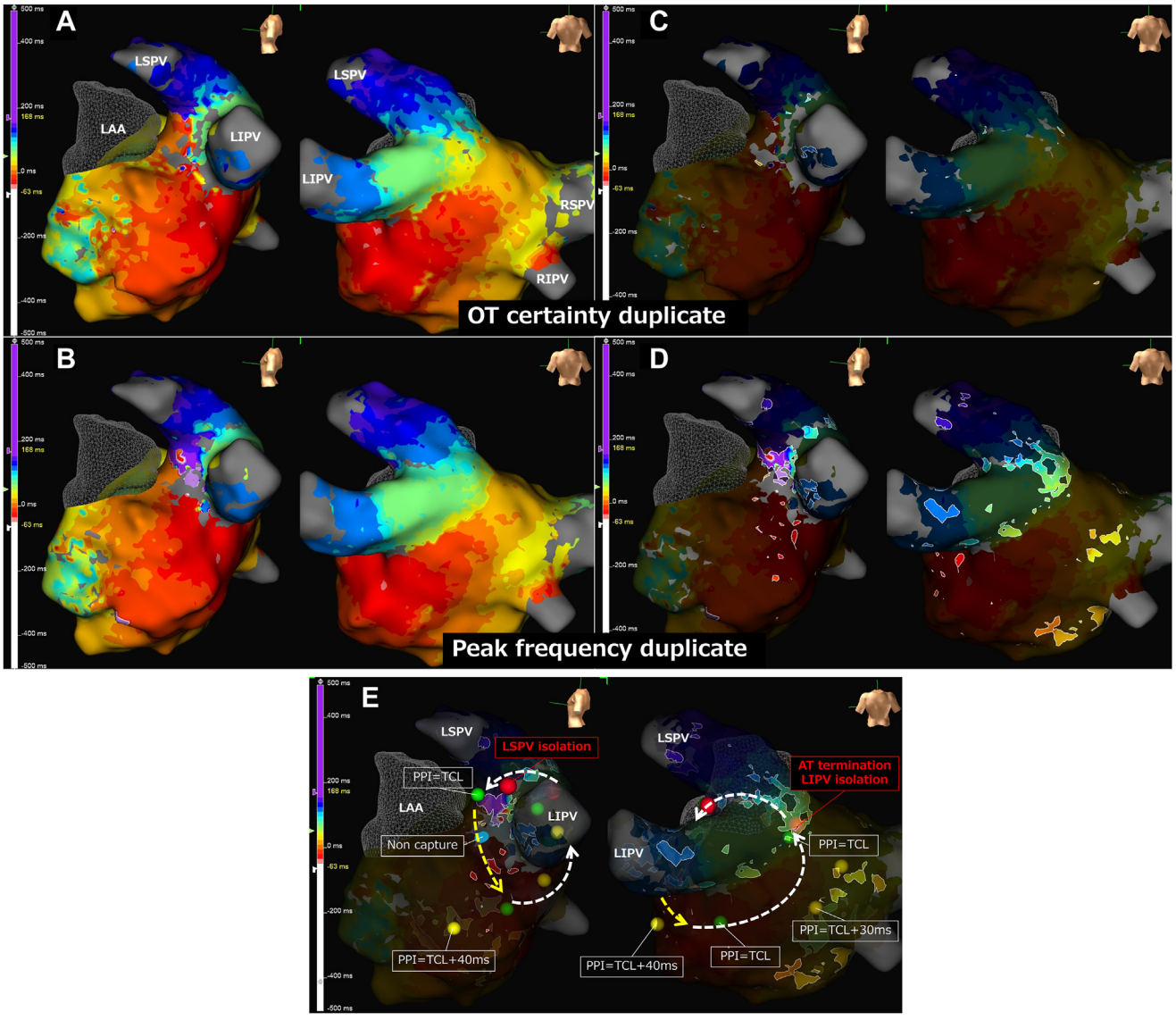

Figure 1 **A:** Late activation time (LAT) mapping with omnipolar technology (OT) certainty duplicate. **B:** LAT mapping with peak frequency duplicate. **C:** Emphasis mapping using activation mapping and peak frequency mapping with OT certainty duplicate (highlighted area: >550 Hz). **D:** Emphasis mapping using activation mapping and peak frequency mapping with peak frequency duplicate (highlighted area: >550 Hz). **E:** Emphasis mapping using activation mapping and peak frequency duplicate. The red tag shows the termination site of the atrial tachycardia (AT) and left inferior pulmonary vein (LIPV) and left superior pulmonary vein (LSPV) isolation sites. Green tags showed a similar site of the postpacing interval (PPI) equal to tachycardia cycle length (TCL). Yellow tags showed that the site of the PPI is longer than the TCL.

was performed in the left atrium (LA) using a high-density grid mapping catheter with the EnSite X EP system (5701 points were used out of 45,185 acquired points). The late activation time (LAT) maps demonstrated just a slight difference between the OT certainty and peak frequency duplicate (Figure 1A and 1B). The emphasis mapping is a combination of different mappings to be displayed together in the same mapping, which helps in understanding more difficult arrhythmia circuits. PV gap sites and critical isthmus were difficult to identify using emphasis mapping (LAT map + OTNF) with OT certainty duplicate even at a frequency threshold of 550 Hz (Figure 1C); however, with peak frequency duplicate created under the same conditions, we could identify and highlight PV gaps and critical isthmus (Figure 1D). Sparkle map with LAT map is shown in Supplemental Video 1. The postpacing interval (PPI) at the left posterior wall, center of the centrifugal propagation site, and posterior carina of the left inferior pulmonary vein (LIPV) were equal to TCL. The PPI at the mitral annulus was longer than the TCL by 40 ms; otherwise, the anterior ridge of the left superior pulmonary vein (LSPV) with a scar area could not have been captured by high-output pacing, which assumes a tachycardia circuit with an epicardial connection. These findings indicated that the AT propagated around the left pulmonary vein in a counterclockwise pattern, with an

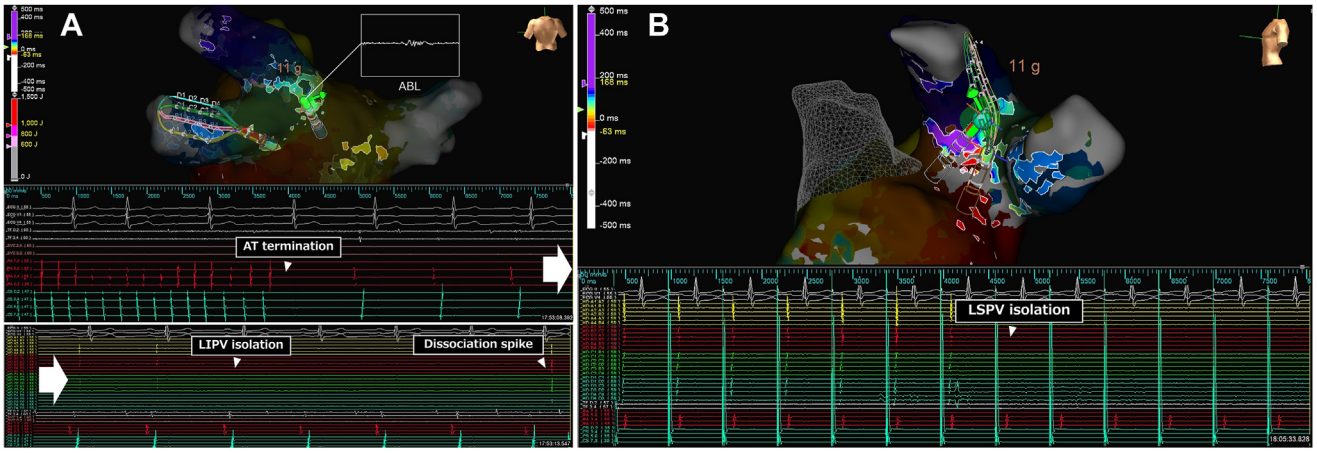

Figure 2 **A:** The atrial tachycardia (AT) was terminated after 1.0 seconds after the initial radiofrequency (RF) application targeting the highlighted area at a frequency >550 Hz. The lower panel shows that the AT was immediately terminated after first RF application at the entrance of the AT. The remaining left inferior pulmonary vein (LIPV) potential disappeared during the first RF application at the AT termination site, and LIPV dissociation spike was observed. **B:** The left superior pulmonary vein (LSPV) was isolated during the first RF application that targeted the highlighted area with a frequency >550 Hz.

entrance site at the LIPV gap and the exit site at the LSPV gap (Figure 1E).

The AT was immediately terminated and returned to sinus rhythm 1.0 seconds after radiofrequency (RF) application using a 4.0-mm irrigated flexible-tip ablation catheter (TactiFlex SE; Abbott) with RF energy between 35 and 40 W with a contact force of 10–15 g at the entrance of the AT on the posterior carina of the LIPV, followed by ablation to close the gap of the LIPV (Figure 2A). The remaining LIPV potential disappeared during the first RF application

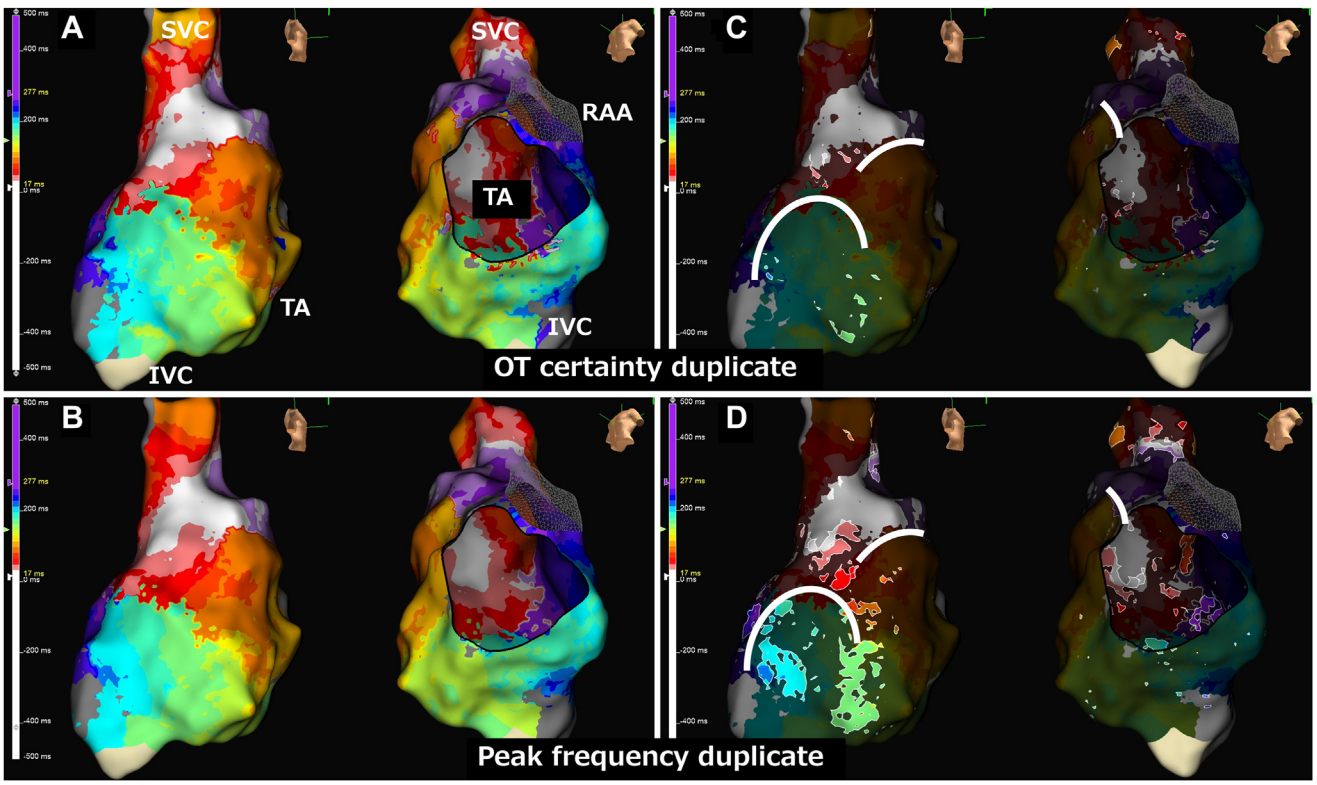

Figure 3 **A:** Late activation time (LAT) mapping with omnipolar technology (OT) certainty duplicate. **B:** LAT mapping with peak frequency duplicate. **C:** Emphasis mapping using activation mapping and peak frequency mapping with OT certainty duplicate (highlighted area: >550 Hz). **D:** Emphasis mapping using activation mapping and peak frequency mapping with peak frequency duplicate (highlighted area: >550 Hz). **E:** Emphasis mapping using activation mapping and peak frequency duplicate. The red tag shows the termination site of the AT2. Green tags showed a similar site of the postpacing interval (PPI) equal to tachycardia cycle length (TCL). White tags showed block line. **F:** AT2 was terminated by the first radiofrequency application targeting the highlighted area at >550 Hz. AT = atrial tachycardia; IVC = inferior vena cava; RAA = right atrial appendage; SVC = superior vena cava; TV = tricuspid annulus.

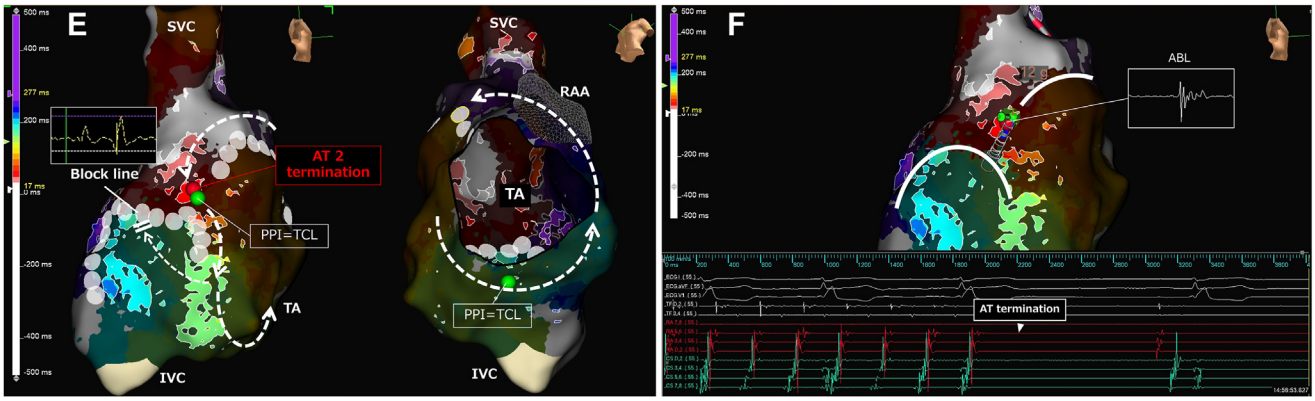

Fig 3 Continued.

to the AT termination site, with an LIPV dissociation spike observed. Additional RF was applied around the AT termination site, and the LSPV potential was isolated by further RF application at the anterior ridge of the LSPV gap, which was highlighted and visualized using peak frequency duplicates in the AT circuit. The LSPV potential was isolated by the first RF application again (Figure 2B). After RF applications, AT was never induced by stimulation with or without isoproterenol infusion. Three months after the procedure, 24-hour ECG monitoring revealed no arrhythmia, and this patient is still free from arrhythmias after 7 months.

Case 2

A 48-year-old male patient with a history of maze procedure for AF was admitted to our hospital for AT ablation. Four years previously, the patient had undergone the maze procedure for persistent AF with mitral valve plasty. AT with palpitations was documented in an outpatient clinic without antiarrhythmia drugs. A 12-lead ECG showed AT with a TCL of 210 ms. Transthoracic echocardiography revealed a normal ejection fraction of 65%. An electrophysiological study and catheter ablation were performed after informed consent was obtained. After transseptal puncture, a high-density mapping during AT was performed at the LA using the HDG mapping catheter. The PPI at the mitral annulus was equal to the TCL. The PPI at the LA posterior wall and septum were longer than the TCL by 40 ms. These findings indicated that the tachycardia was a perimitral flutter (AT1). The AT1 was immediately changed to AT2 with a TCL of 270 ms after RF application using the TactiFlex SE during mitral isthmus line creation. The sequence of the EGMs in the CS changed to a proximal-to-distal pattern. Therefore, AT2 was remapped at the right atrium using an HDG mapping catheter (1705 used points out of 80,172 acquired points). A conduction block was observed at the lateral site owing to surgical procedure (white tags in Figure 3E). The LAT maps demonstrated a slight difference between OT certainty duplicate and peak frequency duplicate (Figure 3A and 3B). The critical isthmus was unclear using emphasis mapping with OT certainty duplicate even at a frequency threshold of 550 Hz (Figure 3C); with peak frequency duplicates created under the same conditions, the critical isthmus was clearly highlighted (Figure 3D). However, the cavotricuspid isthmus area was not highlighted at a high peak frequency. Sparkle map with LAT map is shown in Supplemental Video 2. The PPI at the tricuspid annulus, and highlighted at a high frequency with peak frequency duplicates, were equal to the TCL. These findings indicated that the AT2 propagated around the tricuspid annulus in a counterclockwise pattern, with the circuit going through a conduction gap between the block line of the lateral right atrium (Figure 3E). AT2 was terminated at a high-frequency site between the conduction block lines and returned to sinus rhythm 7.0 seconds after first RF application with RF energy between 35 and 40 W and a contact force of 10–15 g (Figure 3F). After additional RF applications around the success site, AT was not induced by stimulation with or without isoproterenol infusion. Three months after the procedure, 24-hour ECG monitoring revealed no arrhythmia, and this patient is still free from arrhythmias after 6 months.

Discussion

The development of high-density mapping catheters and 3D mapping systems enables the acquisition of thousands of mapping points in a short time. Combining high-resolution activation mapping with high-density voltage and entrainment mapping is useful for identifying the critical part of the tachycardia circuit in endocardial gap-related reentrant AT.[3] Various mechanisms of AT recurrence after the maze surgery have been reported. Suzuki and colleagues[4] reported the electrophysiological findings in 37 patients with AT recurrence after the maze procedure. They discovered that the atrium after the maze procedure contained many electrical gaps, and most of the mechanisms for ATs were macroreentry.

Determining tachycardia circuits is important, particularly in complex arrhythmias. This novel report highlights the innovative software "peak frequency duplicate" with OTNF in EnSite X version 3 for identifying the PV gap and critical isthmus of complex AT cases. OT mapping using an HDG

mapping catheter is a useful tool for acquiring optimal local electrogram signals from omnipolar signals by integrating signals of 3 adjacent electrodes (a clique of 3) organized in a triangular pattern. Moreover, this novel software allows visualization of PV gap and isthmus by annotating the peak frequency with near-field scaling detection, regardless of the local amplitude.

The peak frequency duplicate is an algorithm that prioritizes the point with the highest frequency in the identical region and is expected to map more reliably than conventional OT certainty duplicates. By increasing the confidence slider value of the peak frequency duplicate from 200 Hz to 550 Hz, we could distinctly visualize the complex tachycardia circuits and PV gaps. However, the cut-off value of the peak frequency has not yet been determined, which should be addressed more in the future. In this case, by setting a peak frequency threshold at 550 Hz, we could better identify the critical isthmus of the complex AT circuit and evaluate the PV gap, leading to minimal RF applications to treat these tachycardias. We assumed that the cut-off values for peak frequency duplicates and OT certainty duplicates are different from case to case, thus warranting confirmation in the future.

Conclusion

Here, we report 2 cases of complex AT. A peak frequency duplicate in OTNF is a useful tool for identifying and visualizing both PV gaps and the critical isthmus of complex AT circuits. A high peak frequency threshold of >550 Hz could be a suitable cut-off value for correctly visualizing the critical isthmus and PV gap.

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Appendix

Supplementary Data

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.hrcr.2024.03.007.

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