Coronary Artery Spasms and ST-Segment Elevation During Catheter Ablation of Pulmonary Vein Isolation

— Cause, Mechanism, and Management —

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History of Coronary Artery Spasms (CAS)

Sixty years have passed since Prinzmetal et al first reported the novel disease concept of a variant form of angina characterized by chest pain occurring at rest (from midnight to early morning or during sleep) and transient ST-segment elevation (STE).¹ They suggested that the mechanism of the variant form of angina was increased vessel tonus, because it occurred in the absence of an increase in myocardial oxygen demand. Since then, some investigators have succeeded in demonstrating vasoconstriction (total or subtotal obstruction) of an epicardial coronary artery

Article p264

during a spontaneous angina attack using coronary angiography (CAG).^{2,3} In the late 1970s, some groups found that ergonovine can be used for the CAS provocation test, and diagnostic accuracy dramatically improved thereafter.^{4,5}

Mechanism of CAS

As shown in the **Figure**, CAS can be induced by 2 pathways: (1) hyperreactivity of the coronary artery in response to

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Table. Comparison of 2 Studies of CAS

	Nakamura et al ⁹	Tang et al ⁸
Study design	Retrospective, multicenter	Retrospective, single-center
Total no. of patients	22,232	2,965
No. of patients with CAS or STE (%)	CAS: 42 (0.19%)	STE: 13 (0.38%)
Age, years mean $\pm$ SD	66 $\pm$ 18	57 $\pm$ 8
Male (%)	41/42 (98%)	7/13 (54%)
AF type: Long-standing/persistent/paroxysmal	4/14/24	0/1/12
Smoking (%)	71%	ND
STE-related procedure: Sep.P/LAG/energy delivery	5/0/21	10/3/0
Energy source: RF/Cryo	8/11	13/0
Duration of the STE	ND	4.6 min
CAG during the STE	37/42	0/13
Documentation of spasms during the STE	29/29	0/13
Culprit artery: RCA/LAD/LCX	23/11/0	ND
STE in the inferior leads (%)	79%	100%
Incidence of VF or CPA (%)	7/42 (17%)	0/13 (0%)

AF, atrial fibrillation; CAS, coronary artery spasm; CPA, cardiopulmonary arrest; Cryo, cryoablation; LAD, left anterior descending; LCX, left circumflex artery; ND, not described; RCA, right coronary artery; Sep.P, septal puncture; STE, ST-segment elevation; VF, ventricular fibrillation.

vasoconstrictive factors (e.g., endothelial dysfunction, including atherosclerotic plaque, vascular smooth muscle hyperreaction, passive mechanical collapse, and adventitial abnormalities) and (2) increased activity of vasoconstrictive factors (acetylcholine, catecholamines, histamine, serotonin, an imbalance in the autonomic tone, and inflammatory infiltration).⁶ Some clinical situations, such as smoking, alcohol consumption, and genetic factors are very well known as background to promoting CAS.^{6,7}

STE During Catheter Ablation

Tang et al first reported the incidence and characteristics of STE during standard radiofrequency (RF) ablation for circumferential pulmonary vein isolation (PVI) in a large number of patients.⁸ Their single-center study demonstrated that the STE event rate was 0.39% (13/2,965), and all occurred after transeptal puncture or pulmonary vein venography. Although an air embolism or Bezold-Jarisch like reflex leading to CAS was suggested as the cause of the STE, the obvious etiology of STE was not fully investigated in that study.

In this issue of the Journal, based on their corresponding large-scale multicenter study, Nakamura et al⁹ clearly demonstrate an incidence of CAS related to AF ablation of 0.19% (42/22,232), and CAS was the major cause of STE during PVI ablation. They performed emergency CAG in 88% (37/47) of the patients, and reversible spastic lesions occurred in all (29/29) patients who had continued STE during CAG. However, we should be aware that Nakamura et al only collected subjects with an exact or highly suggestive diagnosis of CAS.⁹ Therefore, from the point of view of "STE" including air embolisms or thromboembolisms, the clinical manifestation of STE may be more frequently observed, as Tang et al described.⁸ The **Table** shows a comparison of the results from Nakamura et al⁹ and Tang et al.⁸ In the former study, an autonomic imbalance was highly suggested as the cause of the STE (CAS) because it particularly occurred during cryoablation of the left PVs. Cryoablation is thought to have a strong effect on the

epicardial ganglionated plexi, which often exist close to the left PVs.⁹⁻¹¹ In contrast, in the latter study all STE events were unrelated to energy delivery to the PVs but were related to the contrast injection procedure (septal puncture in 10, PV venography in 3 patients). That suggests air embolisms as the major cause of the STE; however, Nakamura et al also described 5 patients who had CAS immediately after septal puncture.⁹ Tang et al considered that the passage of the catheter through the atrial septum, which is innervated profoundly by parasympathetic nerves, might irritate or damage the plexus.⁸ Another possible explanation for the difference between the studies is the energy sources that they used. Tang et al used RF ablation in all patients, whereas Nakamura et al performed cryoablation in 14.7% of the patients, and showed an approximately 10-fold higher incidence of CAS during cryoablation than RF ablation (0.33% vs. 0.04%).

Risk of CAS (STE) During PVI

Nakamura et al demonstrated 3 different risk factors for CAS during PVI: male sex, smoking, and a cooled energy source (cryoablation).⁹ However, because they did not collect detailed patient data in those without CAS, the exact estimation of the risk for CAS or VF/CPA in the patients with all 3 conditions is impossible. Therefore, what we should know at the present time is that CAS is rare (0.2%) in general but possibly critical (17% of CAS, absolute risk of 0.03%) during the PVI procedure. Further, physicians are recommended to pay much attention to any ST-segment changes in the inferior ECG leads, especially when they perform PVI using a cryo-balloon catheter in male patients who are current cigarette smokers.

Disclosure

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