The Application of Coronary Contrast Emptying Time in Diagnosing Coronary Slow Flow Phenomenon: A Serial Case Report

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ABSTRACT

The Coronary Slow Flow Phenomenon doesn't achieve as much attention as its counterpart Coronary Arterial Disease because it is considered a rather benign entity. But now it is proven that coronary slow flow phenomenon can also manifest as an acute coronary syndrome, myocardial ischemia, malignant arrhythmia, and even sudden cardiac death.

This entity is usually diagnosed from coronary angiography study when a delayed coronary contrast filling time is found without the presence of significant epicardial narrowing of the related arteries. But, in our center's years of experience, we frequently found cases in which myocardial ischemia or infarction was suggested or proven clinically, on the other hand, angiography study showed no significant epicardial coronary artery narrowing neither delayed coronary contrast filling time. Furthermore, we observed that this group of patients exhibited a rather prolonged coronary contrast emptying time instead.

In this serial case report, we presented some of our cases where microvascular disorders were suspected. We demonstrated that not all coronary contrast filling times in ischemic or infarction-related arteries were prolonged, on the other hand, prolongation of coronary contrast emptying time showed a more consistent result.

Keywords: *Coronary Slow Flow Phenomenon, Microvascular disorder, myocardial ischemia, myocardial infarction.*

INTRODUCTION

Traditionally, the coronary Slow Flow phenomenon is an angiographic entity characterized by delayed contrast filling of distal coronary arteries without significant stenotic lesions. Non-significant stenotic lesion defined as a stenotic lesion with less than 40% lumen diameter reduction.[1] Delayed contrast filling was commonly diagnosed either with Gibson's or TIMI method. Based on Gibson criteria, diagnosis of a delayed contrast filling is when the total frame count from the moment contrast entered the proximal of the related coronary artery until it reached the distal end exceeds 27 frames, with 30 frames/second angiographic frame speed. Meanwhile, LAD needs a correction factor, where the total frame count should be divided by 1.5. Whereas with TIMI criteria,

a delayed contrast filling is diagnosed when the time from the moment contrast entered the proximal of the related coronary artery until it reached the distal end takes more than three heartbeats. Other methods for measuring coronary blood flow velocity, such as the one that Gibson proposed using guidewire and Kelly clamps, were not commonly used.[2,3,4]

Years of experience in our center showed frequently found cases that do not fit the delayed filling time criteria by Gibson's or TIMI method but with clear myocardial ischemic or infarction evidence. The current method for diagnosing coronary slow flow phenomenon based on measuring contrast filling time can only detect this abnormality in its intermediate and late form. Thus, we propose coronary contrast emptying time measurement as a marker to diagnose coronary slow flow phenomenon in the earlier stage. We define coronary contrast-emptying time as the period that starts when it entered the related artery until its complete emptying with prolonged emptying time is more than 3 seconds (45 frames with 15 frames/second angiographic frame speed or 90 frames with 30 frames/second angiographic frame speed).

In this serial case report, we presented coronary slow flow phenomenon cases in our center. We demonstrate the measurement of coronary contrast emptying time and its comparison to Gibson's method for diagnosing coronary slow flow phenomenon. Here, we presented four patients whom we suspected to have myocardial ischemia or infarction episodes.

CASE ILLUSTRATION

The first case was a 35-year-old woman. She has no previous history of chest pain, neither history of diabetes or hypertension. She was complaining of squeezing chest pain started 2 hours before admission. On anamnesis, she informed that her father died after collapsing suddenly. The patient hemodynamic was stable. The ECG recording showed an ST elevation in septal and lateral leads. Further echocardiography examination showed a hypokinetic movement of basal and mid anteroseptal with a 45% ejection fraction.

There was no significant coronary lesion found during a coronary angiography study. The study showed filling time of LAD was 26,6 total frame count (with a picture-taking speed of 30 frames per second), which is within range. However, the coronary contrast emptying time was prolonged, with a total of 136 frame counts (with the picture-taking speed of 30 frames per second). Meanwhile, the filling time of LCx was within the recommended filling time limit (26 total frame counts). However, coronary contrast emptying time was prolonged, which was 110 total frame count. Filling time in RCA was 38 total frame count, which is also longer. Coronary contrast emptying time of RCA was 132 total frame count, showing another prolonged duration.

The second case was a 34 years old male who came to our clinic with chest discomfort on performing moderate activities. He also complained of having some palpitation episodes and get fatigued while performing daily activities. Fixed splitting of second heart sound was present. Otherwise, the physical examination findings were unremarkable. The ECG recordings showed a first-degree AV block with interchanging morphology between complete and incomplete RBBB. Cardiac MRI showed dilatation of theright atrium and right ventricle with mild tricuspid regurgitation, whereas left ventricle structure and function showed no abnormalities.

There was no significant coronary lesion found during a coronary angiography study. The study showed a total of 20 frame counts of LAD, which is normal. Yet coronary contrast emptying time was prolonged, with a total of 92 frame counts. The filling time of LCx was prolonged as well, with a total of 32 frame counts. Coronary contrast emptying time was 92 total frame count, which also showed a prolonged duration. Furthermore, the filling time and coronary contrast emptying time of RCA show an increment, with 46 frame counts and 178 total frame counts, respectively.

The third case was a 41 years old male. He was referred to our hospital with retrosternal chest pain starting 7 hours before admission. The patient was a smoker and had a history of dyslipidemia before, with other physical examinations showing normal findings. The

electrocardiography examination showed a marked ST elevation on inferior leads. The patient then underwent a fibrinolytic procedure successfully. Echocardiography showed concentric left ventricular hypertrophy with preserved systolic function.

There was no significant coronary lesion found during a coronary angiography study. The study showed filling time of LAD was 32 total frame counts, which showed a prolonged filling time. Coronary contrast emptying time was longer, with 104 frame counts. The filling time of LCx was good, with 26 total frame counts. However, the coronary contrast emptying time was 104 frame counts, which showed a prolonged duration. Filling time in RCA was also good, with 24 frame counts. Coronary contrast emptying time of RCA was 150 total frame count, which showed a marked prolonged duration.

The fourth case was a 45 years old female who came to our hospital with the typical chest pain symptoms, induced by moderate activities such as walking 100 meters or climbing stairs, but further relieved with short rest. The patient has a history of hypertension for four years, which she consumed amlodipine 5 mg daily. Physical examinations on the patients show no remarkable findings. The electrocardiography displayed a complete LBBB with ST- elevation on avR. Meanwhile, the echocardiography showed left ventricular hypertrophy with a 63% ejection fraction, with no segmental wall motion abnormalities.

There was no significant coronary lesion found in the coronary angiography study. Its filling time was 24 total frame counts. Nevertheless, its coronary contrast emptying time was 108 total frame count, which fulfilled our criteria as prolonged contrast emptying duration. Although the coronary contrast emptying time increased to 96 frame counts, the filling time of LCx was good, with a total of 26 frame counts. Filling time in RCA was 32 total frame counts, which showed a prolonged duration. Coronary contrast emptying time of RCA was 110 total frame count, which is long.

DISCUSSION

We proposed several postulates to explain why measuring the coronary emptying time as a whole is critical in assessing coronary microvascular disorders and not just coronary filling time. Classically, there are two compartments of coronary vasculature, which are epicardial coronary arteries and microvascular. There are three subcategories for microvascular, which are arteriole, periarteriole, and capillary beds. In normal conditions, arteriole contributes to 25% of total blood flow resistance in the coronary vasculature, arteriole contributes to 55% of total resistance, while the rest comes from capillary beds. Several different factors play roles in regulating microvascular tones.[5]

Endothelial and neural factors, mainly induced by the shear stress of the vascular wall, regulate periarteriole and large-arteriole tones. Meanwhile, the myogenic factors and physical factors control the medium-sized arteriole tones. Take, for example, the presence of extravascular compression and increased intraventricular end-diastolic pressure. Metabolic factors, on the other hand, regulate the small-sized arteriole tones. While we have a predominant mechanism for controlling resistance on each part of the microvascular compartment, this is more like a continuum than a clear-cut separation.[5]

Table 1. Summary of myocardial ischemia/infarction in each patient, with coronary filling time dan emptying time measurements

Patient	Evidence suggesting myocardial ischemia/infarction	Coronary Filling time			Coronary Emptying Time		
		LAD	LCx	RCA	LAD	LCx	RCA
35 years old woman	Anterolateral ST elevation Hypokinetic wall motion of anteroseptal LV wall on echo	26.6	26	38	136	110	132
34 years old male	Palpitation and fatigueness 1st degree AV block with RBBB	20	32	46	92	92	178
41 years old male	Inferior ST elevation	32	26	24	104	104	150
45 years old female	Typical chest pain Complete LBBB	24	26	32	108	96	110

In coronary angiography study, the first compartment blood and contrast entered after occupying epicardial arteries is arterioles-large arterioles compartment. When the blood can not enter the arterioles-large arterioles compartment, the coronary angiography contrast will also face difficulties in occupying epicardial space, known as the delayed filling time in the slow coronary flow phenomenon. Endothelial dysfunction and subclinical atherosclerosis are widely accepted. They are also the most studied etiologies for the slow coronary flow phenomenon. Cin and colleagues on their study with intravascular ultrasound found a diffuse intimal thickening and widespread calcification with no luminal irregularities observed from coronary angiography in patients with coronary slow flow phenomenon. In other study, Pekdemir and colleagues also found increased endothelin-1 concentration in coronary slow flow patient during rapid atrial pacing compared to patient without coronary slow flow phenomenon. These entities will affect primary, large arterioles, and also a proportion of medium-sized arterioles. So our first suggestion is that a milder but more diffuse form will cause difficulties of blood entering the 'medium-sized arterioles' compartment on coronary angiography study, which in turn will cause difficulty for contrast entering the 'prearteriole- large arteriole' compartment. Rather than delayed contrast filling, this phenomenon will manifest more as delayed contrast emptying.[6,7,8]

Several factors theoretically might contribute to microvascular disturbance but are not as extensively studied. Those factors are the physical factors, myogenic and metabolic factors. Since they mainly affect medium to small-sized arterioles resistance, these factors will cause delayed contrast emptying rather than filling in coronary angiography. It further lays the foundation for the second suggestion where physical factors like left ventricular hypertrophy and myocardial fibrosis could contribute to coronary microvascular disorders incidence. Furthermore, it manifests as delayed contrast emptying time rather than filling time on coronary angiography.[8]

Although we emphasize the contrast emptying time aspect of the microvascular disorder, its measurement should not be separated from contrast filling time measurement. The reason is that we accept that endothelial dysfunction and subclinical atherosclerosis are the main risk factors for the slow coronary flow phenomenon until now. Moreover, these compartments previously described are a continuum rather than separate compartments. Thus, we propose new criteria for diagnosing slow coronary flow phenomenon with coronary contrast emptying time, which counts from the first time the contrast entering the related epicardial arteries until it fully empties from that artery. This process will take no more than three seconds.

Epicardial coronary stenosis can have a direct impact on coronary filling time. Its presence consequently excludes the diagnosis of coronary slow flow phenomenon by Gibson's criteria. Ramakrishnan and his colleagues from their observational study concluded that dyslipidemia, hypertension, and smoking are strongly associated to coronary slow flow phenomenon incidence. Since they have relatively the same risk factors, these two entities can be present in one patient at once. Patel and colleagues demonstrated the presence of these two entities at once on her study by measuring myocardial perfusion at rest and stress with quantitative positron emission tomography. That is why we also propose that in the significantly narrowed epicardial coronary artery, prolongation of coronary emptying time with a normal-filling time could indicate a presence of microvascular disorder in conjunction with epicardial stenosis.[9,10]

Different operators lead to the variability of contrast injection duration, and it will cause bias without using an automatic contrast injector device. Thus we proposed the contrast injection duration to be 1 to 1,5 seconds for three cc contrast each shot.

CONCLUSION

We propose that measurement of epicardial contrast duration might serve as a better marker in terms of sensitivity than measurement of contrast filling time.

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