Reversed sharp and dull sequence of double potentials in coronary sinus during orthodromic reciprocating tachycardia

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Introduction
The mechanism of the occurrence of double coronary sinus (CS) potentials observed during orthodromic reciprocating tachycardia (ORT) has been described in only a limited number of publications. The vast majority of these cases presented with a double potential in a first dull and second sharp sequence, which indicates that the left atrium (LA) myocardium activates earlier than the CS musculature. In this paper we describe the reversed phenomenon of double potentials during ORT, indicating the isolated insertion of the accessory pathway (AP) into the CS musculature.

Case report
A 25-year-old man with documented supraventricular tachycardia was admitted to our clinic for an electrophysiological study and catheter ablation. The patient’s baseline electrocardiogram did not show any evidence of pre-excitation. The standard electrode catheters were placed at the high right atrium, the His region, and the right ventricular (RV) apex. A 6F decapolar diagnostic steerable catheter (Inquiry; Abbott, Minneapolis, MN) with 2-mm electrodes and 4-mm interelectrode spacing was introduced into the CS. During baseline sinus rhythm, single atrial potentials were recorded on the CS electrode catheter with an activation sequence in a septal-to-lateral direction. The constant RV pacing and RV extrastimulus testing revealed nondecremental, eccentric retrograde atrial activation. The earliest atrial activation was registered at the distal CS. The CS catheter was then carefully inserted deeper to the point of the earliest activation registered on CS 3/4. Narrow QRS and long R-P tachycardia was induced via programmed RV stimulation, with a tachycardia cycle length of 340 ms. These findings during the electrophysiological study definitively indicate that the tachycardia was ORT incorporating a concealed-type left lateral AP.

The double atrial potentials (DP1 and DP2) recorded during tachycardia on the CS electrode catheter caught our attention. Activation of the first component (DP1-Sharp) of the double atrial potentials started from a site close to the AP insertion (CS 3/4) and propagated bidirectionally in a lateral and the septal direction. The second component (DP2-Dull) of the double potential propagated from the septal-to-lateral direction (Figure 1). These findings were also noted during constant RV pacing. The sequence of the double CS potentials varied during sinus rhythm, RV pacing, and premature atrial complexes from distal CS and right atrium (Figure 2).

After transseptal puncture the LA and the mitral annulus were mapped during RV pacing with the use of an irrigated ablation catheter. The mapping identified the earliest activation site at the lateral mitral annulus. After delivery of the first radiofrequency energy (35 W) toward this target site during constant RV pacing, ventriculoatrial block over the AP occurred and the tachycardia was no longer inducible. In total, 4 radiofrequency applications (2 from the atrial and 2 from the ventricular sides) were delivered. After ablation decremental ventriculoatrial conduction over the atrioventricular (AV) node was registered, with fusion of DP1 and DP2 along the CS, similar to the CS activation front during the sinus rhythm (Figure 2E and 2F).

Discussion
In an anatomical and histological study, Chauvin and colleagues1 described the connections of the muscular architecture of the CS to the LA myocardium. In all necropsied heart specimens, the venous wall of the CS was surrounded by a continuous cuff (up to 40 mm in length) of striated muscle and terminated close to the Vieussens valve. The thickness

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of this muscular cuff compounded up to 2.5 mm and mostly was greater at the level of the ostium than at the other end. The LA myocardium and the CS muscle cuff were separated by adipose tissue. All specimens showed connections between the CS musculature and the LA myocardium, which were mostly oriented obliquely and leftward toward the LA myocardium. No connections were found between the CS musculature and the left ventricular myocardium in this study. Twenty percent of the connections were discrete and limited to 1 or 2 fascicles. In the majority of cases the connections were multiple and wide.1 The clinical presentation of the musculature (ie, electrical) connections between the CS and the LA myocardium and importance of its interpretation in patients with concealed AP has been described in a limited number of publications.2–4 The CS musculature produces larger and sharper potentials, whereas activation of the LA presents smaller, blunt “far-field” potentials. In describing these 2 types of potentials we use the terms sharp (CS potential) and dull (LA potential). In the case of retrograde conduction through the left-sided AP, the double potential can occur only in the case of limited connection between the CS and LA musculature (eg, when this connection is presented only proximally and not distally). Akiyama and colleagues2 examined the clinical significance of double potentials recorded in CS during retrograde AP conduction and their association with the CS musculature in 11 patients. The double potentials were defined as discrete deflections separated by an interval of >10 ms at all recording sites within the CS and were recorded during ventricular pacing or orthodromic AV reentrant tachycardia. All patients in this cohort underwent AP conduction directly with the LA, resulting in a dull-sharp sequence in all cases. Akiyama and colleagues revealed that according to the localization of the AP insertion in the LA, there are 3 main patterns of double potential phenomenon, designated as follows: (A) left lateral AP: the LA activation (dull) is distal to proximal, whereas the CS activation (sharp) is proximal to distal; (B) left posterolateral AP: the LA activation spreads simultaneously proximally and distally, whereas the CS activated is still proximal to distal; (C) posteroseptal AP: the LA and CS both activate in a proximal-to-distal sequence. Most recently, triple atrial potentials were described on the CS electrode catheter during ORT, incorporating a concealed-type left posterolateral AP.1 Activation of the first component (dull) started from a posterolateral site close to the AP insertion and propagated bidirectionally toward the lateral and the septal direction. The last component (sharp) propagated from a proximal-to-distal direction. The small atrial potentials were recorded consecutively between these 2 potentials via the mid and proximal CS bipolar recording electrodes, with the activation sequence from the lateral-to-septal direction. These findings were also reproduced during constant RV pacing. In other words, the authors described the case of B

**Figure 1**  
A: Tracing during orthodromic reciprocating tachycardia: clear demonstration of double potential on the coronary sinus (CS) catheter with a sharp-dull sequence. Earliest activation of the CS musculature (DP1; sharp potential) on the distal end of the CS catheter while the left atrial activation (DP2; dull potential) is proximal to distal. B: Schematic demonstration (left anterior oblique projection) of the retrograde activation of the CS musculature and the left atrium. AP = accessory pathway; MV = mitral valve; TV = tricuspid valve.
Figure 2  

A: The sinus beat depicts a concentric activation front on the coronary sinus (CS) catheter; there is no clear evidence of double potentials.  

B: The premature right atrial complex demasks the double potential (a dull-sharp sequence).  

C: The double potential: a sharp-dull sequence presented by premature complex from the distal CS.  

D: Right ventricle (RV) pacing before ablation demonstrates eccentric activation front and double potential on the CS catheter in a sharp-dull sequence, as during the tachycardia.  

E: RV pacing after ablation depicts a concentric activation front on the CS catheter.  

F: Left ventricle (LV) basal pacing with ablation catheter after ablation depicts a concentric activation front on the CS catheter. Note that in A and C planes right bundle branch block is present, which was intermittently induced mechanically during the electrophysiology study. HRA = high right atrium; PAC = premature atrial complex; RA = right atrium; SR = sinus rhythm.
pattern (according to Akiyama and colleagues) with electrophysiological presentation (third potential) of the discrete oblique connection between the CS and LA, as it was presented in the previous anatomical study.\(^1\)

In our case, we present the reversed pattern, with first sharp and second dull potentials. The first activation sequence of CS (DP1-sharp) was distal to proximal, whereas the second activation sequence of LA (DP2-dull) was proximal to distal on the CS electrode. This is a first description of the reversed sharp and dull sequence of double potentials in the CS during ORT and RV pacing (reversed A pattern, according to Akiyama and colleagues).

The pattern described above is attributable to the AP insertion into only the CS musculature and a lack of distal connection between the CS and the LA. In contrast to our finding, Enjoji and colleagues\(^4\) described insertion of the AP distally into the CS musculature with an additional distal connection between the LA and CS. Therefore, they observed a similar pattern of CS activation as in our case, only after a failed ablation from the LA side, while after first applications the CS–LA muscular connection was disconnected, but not the AP.

### Conclusion

CS double potentials represent the potentials of the LA and CS musculature. In the vast majority of the cases the double potential has a dull-sharp sequence. To the best of our knowledge, this is the first report of a reversed sharp-dull sequence of double potentials during the orthodromic AV reentrant tachycardia, which helped to verify the AP insertion localization before the ablation procedure.

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