A balloon occlusion technique to overcome the convective warming effect of coronary sinus blood flow on cryoablation

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Introduction

Since its first human application in 1998,[1] transcatheter cryoablation has emerged as a viable alternative to radiofrequency ablation. Its enhanced safety profile, including an obligatory phase of reversible tissue inhibition prior to permanent cellular damage, has rendered cryoablation an attractive treatment option for perinodal and peri-Hissian substrates.[2] Several factors may influence the creation of effective and durable cryoablation lesions, including electrode-tip size, cooling rate, nadir temperature, electrode-tip-to-tissue contact pressure and orientation, duration of freezing, number of freeze–thaw cycles, and convective warming by local blood flow.[3] Under certain circumstances, the warming effect of high blood flow rates may have desirable consequences. For example, blood flow within adjacent vascular structures, such as coronary arteries, affords natural protection against inadvertent corollary damage. However, convective warming of the catheter tip and targeted tissue has a detrimental effect on lesion formation.[3]

Case presentation

A 52-year-old woman with a long-standing history of paroxysmal atrial tachycardia was admitted for catheter ablation in the context of progressive symptoms. Her past medical history was otherwise unremarkable. Preprocedural echocardiography was normal, and a 24-hour Holter monitor documented multiple brief runs of atrial tachycardia. The electrophysiological study was performed under conscious sedation with the assistance of a 3-dimensional electroanatomic mapping system (EnSite NavX, St Jude Medical, St. Paul, MN). There was no evidence of dual atrioventricular nodal physiology and no accessory pathway. A sustained focal atrial tachycardia was inducible by atrial burst pacing. The site of origin, indicated by the asterisk in Figure 1A, was mapped to the para-Hissian region posterior to the best His recording (red sphere) and anterior and superior to the ostium of the coronary sinus (CS). The local atrial electrogram preceded the surface P wave by 20 ms, was fractionated, and had an initial sharp negative deflection on the unipolar recording. At this site, cryoablation was repeatedly attempted. Despite an initial prompt drop in catheter-tip temperature indicative of good contact with the endocardium, applications were automatically interrupted owing to a high level of refrigerant flow (error message #50030). Rebooting the system and sequentially replacing the coaxial umbilical, cryocatheter, and cryoconsole failed to rectify the problem. We hypothesized that warming blood flow from the CS directed towards the cryocatheter tip prevented the temperature from cooling sufficiently to produce an effective ablation lesion. No attempt was made to target the atrial tachycardia with radiofrequency energy from the noncoronary aortic cusp.[4]

The CS ostium was cannulated by means of a deflectable quadripolar catheter (Live Wire Medium Sweep; St Jude Medical, St. Paul, MN) over which a long sheath was advanced (9F CPS Direct SL II RS 47 cm; St Jude Medical, St. Paul, MN). A venogram balloon catheter (Attain Clarity 6215-80 cm; Medtronic, Minneapolis, MN) was inserted into the CS through this sheath. The balloon was inflated to occlude CS blood flow, after which cryoablation was reattempted. The system shut down and the same error message appeared. As illustrated in Figure 1B, CS venography revealed residual contrast leak with the jet oriented towards the site of ablation (*white arrow*). The 6F decapolar CS catheter appeared to prevent complete CS occlusion and was, therefore, withdrawn. The balloon catheter was advanced to a narrower portion of the CS where balloon inflation resulted in complete occlusion of CS flow, depicted in Figure 1C. During CS occlusion, cryoablation (*asterisk*) was successfully performed at a temperature of −80°C, effectively terminating the atrial tachycardia. Upon balloon

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ABBREVIATIONS CS = coronary sinus
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KEY TEACHING POINTS

- Several factors may influence the creation of effective and durable cryoablation lesions, including electrode-tip size, cooling rate, nadir temperature, electrode-tip-to-tissue contact pressure and orientation, duration of freezing, number of freeze–thaw cycles, and convective warming by local blood flow.
- Convective warming, such as by coronary sinus blood flow, can decrease the size of the ice ball that forms on the cryocatheter tip, thereby exposing a smaller segment of tissue to destructive freezing temperatures. This ultimately results in smaller and less effective ablation lesions.
- Herein, we describe a novel technique consisting of balloon occlusion of the coronary sinus in order to overcome the deleterious warming effects of coronary sinus blood flow on cryoablation lesions in proximity.

re-inflation, a second 4-minute cryoablation application was delivered at the site of success. The atrial tachycardia was rendered noninducible. The procedure was without complication, and the patient was discharged the following day.

Discussion

The effect of convective flow on radiofrequency ablation lesion size is well known and has spawned the development of irrigated catheter technology. Under similar conditions, radiofrequency ablation lesion size increases proportionally with flow rate such that low flow environments produce the smallest lesions. It is known, but perhaps underappreciated, that the opposite occurs with cryoablation. Convective warming from high flow settings decreases the size of the ice ball that forms on the cryocatheter tip, thereby exposing a smaller segment of tissue to potentially destructive freezing temperatures.[5] Indeed, in an in vitro experiment of porcine hearts maintained at 37°C in a controlled saline bath, superfusate flow at 120 mL/min (37°C) directed over the cryocatheter electrode–tissue interface through a plastic cannula (1 cm in diameter) resulted in a 72% reduction in lesion volume compared to no flow.[6]

Our case highlights the clinical potential for convective warming of the cryocatheter electrode–tissue interface by local blood flow to not only interfere with lesion size but prevent attaining temperatures required for ablation. As demonstrated angiographically, the geometric orientation of the CS ostium and Thebesian valve were such that CS blood flow was directed towards the cryocatheter electrode–tissue interface. In subjects with normal coronary arteries, the mean CS blood flow rate was determined to be 122 mL/min (range 83–159 mL/min)[7] and, thus, was within the range described by in vitro studies to impede the creation of effective cryoablation lesions. In our case, partial balloon occlusion of CS flow did not have the desired impact, since the residual stream remained directed towards the ablation area of interest. However, complete balloon occlusion of CS flow allowed us to proceed with effective cryoablation. This balloon occlusion technique could, therefore, be added to the electrophysiologist's armamentarium as a potential solution to overcoming the deleterious impact of convective warming from CS blood flow on cryoablation lesions.

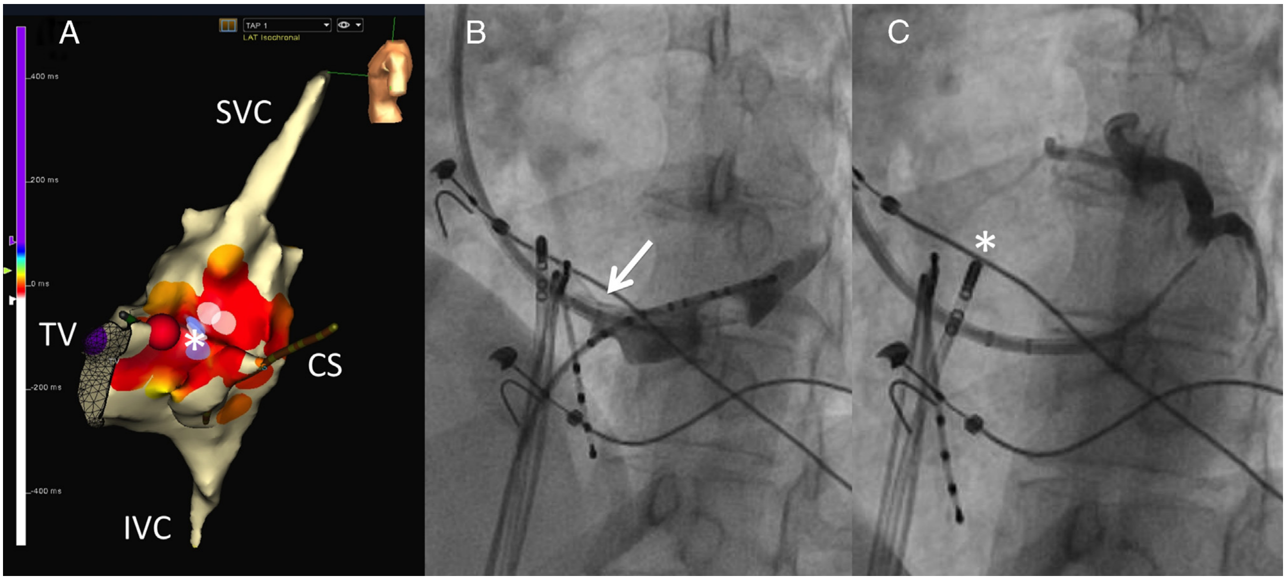

Figure 1 The site of earliest atrial activation during tachycardia is indicated by the asterisk on the electroanatomic map in Panel A and the fluoroscopic image in Panel C. Of note, in Panel B, CS venography was not performed during cryoablation, such that the cryocatheter had migrated lateral to the site of origin of the atrial tachycardia (See text for details). CS = coronary sinus; IVC = inferior vena cava; SVC = superior vena cava; TV = tricuspid valve.

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