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Editorial

Covered Stent Correction of Sinus Venosus Atrial Septal Defects—Continued Technical Modifications Drive the Procedure Forward

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Covered stent correction (CSC) of sinus venosus atrial septal defects (SVASDs) now rivals surgical repair as a treatment strategy in suitable patients.[1] While the first patients to undergo this procedure were considered to have specific variants of the defect, it is apparent that 75% or more of these patients may be suitable for a minimally invasive treatment that allows the majority to go home and resume normal activities within 1-2 days of the procedure.[2–5] As with many new procedures during the developmental stage, there have been continued modifications (Table 1) that have helped to extend the application to more patients while reducing complications.[1–12] Balloon-expandable stents remain the most commonly used stents, although self-expanding stents may yet have a role.[1,13]

In this issue of *JSCAI*, the case series by Sivakumar et al[12] develops the procedure of CSC for SVASD further. They introduce a new

Table 1. Technical advances in covered stent correction for sinus venosus atrial septal defects.

Technique	Purpose	Disadvantages
10 zig CCP 5-6 cm long[1,4–6]	Allows use of single stent that can dilate up to 34 mm for the wide SVC-RA junction	Larger diameter femoral sheath. Over expansion shortening may cause stent to prolapse into left atrium causing a leak
10 zig CCP 7-11 cm long[1,4–6]	For patients with a wide SVC to avoid use of additional stents and allow full dilation without too much shortening	If too long could compromise tricuspid valve inflow[11] and be a nidus for in stent thrombus[1]
Anchor stent[1,4,5]	Prevents a stent with a short apposition zone in SVC from migrating	If too long could occlude the innominate vein
Landing zone stent[1]	A bare metal stent (better gripping to SVC?) provides a platform in which to deploy the covered stent	Covered stent can migrate from landing zone stent when dilating the caudal end of the stent to achieve a seal—during the procedure or later
Sandwich stent[1,6,7]	Locks the covered stent onto the landing zone stent to prevent late migration	Expensive—requires use of 3 stents automatically when 1 long stent might suffice.
Jugular suture control[1,6,8,9]	Thread through the top zig of stent exiting the jugular access site controlling the stent position accurately	Thread needs to be removed before anchor stent. Will not prevent migration if inadequate apposition to SVC. No reports of thread breaking or not detaching
2 simultaneous stents on 1 balloon[1,5]	Produce stent longer than available or allows a hybrid covered/uncovered stent anchor to be deployed instantly	Long balloons required. More expensive than 1 long stent
Stent suturing[10]	Produce stent longer than commercially or regulatory available	Stents come apart when dilating. Availability of longer stents or overlapping 2 on 1 balloon is more controlled
PV protection[1,4–6]	Prevents over distension of stent into pulmonary venous pathway to LA	May prevent complete sealing of stent at PV to SVC junction and cause residual shunting
PV rescue[1,9,11]	If a stent is overdilated into pulmonary venous pathway, can mold stent toward SVC and restore adequate flow	May not always dilate enough or may compromise SVC flow if there is too little space to share
Hybrid stent (Optimus and Zephyr)[5,11]	Cranial bare stent gives additional longer anchoring without obstructing additional veins or innominate vein	Visualization of covered/noncovered portion not always easy allowing malposition of covered end. Adjustment of lengths not possible as with 2 stents on 1 balloon. Bare stent could still crush orifice of additional PV
Stent deployed on 2 guide wires[12]	Allows accurate positioning of stent covering of hybrid stent so that additional veins or innominate vein are not obstructed by stent covering	Second guide wire or guiding catheter could be trapped in stent struts particularly if PV ostium has oblique entrance into the SVC

LA, left atrium; PV, pulmonary vein; RA, right atrial; SVC, superior vena cava.

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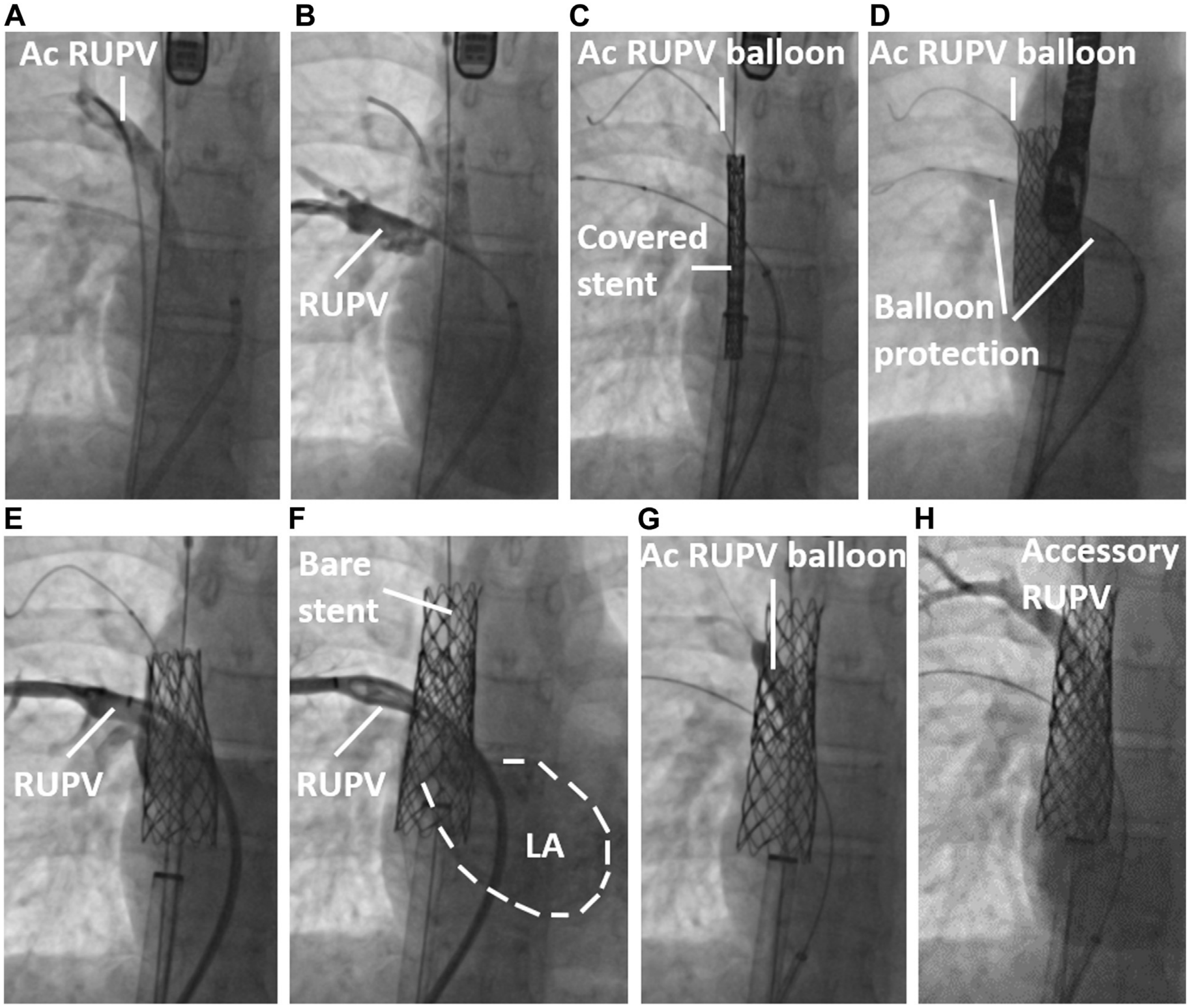

Figure 1.
(A) The accessory right upper pulmonary vein (Ac RUPV) is seen draining high into the superior vena cava (SVC). (B) The main right upper pulmonary vein (RUPV) is seen draining into the SVC-right atrial junction. (C) A 10 zig CCP stent is mounted on a 24-mm BiB balloon (Numed) and a 10-mm × 4-cm Mustang balloon whose distal portion is in the Ac RUPV. (D) A 14-mm Atlas balloon is inflated in the RUPV to protect the pathway as the covered stent is deployed. (E) The RUPV drains to the left atrium (LA). (F) A bare metal stent (10 zig CCP) is placed to overlap and anchor the covered stent with free unobstructed RUPV flow to the LA. (G) The bare stent struts are crossed into the Ac RUPV to dilate the orifice. (H) Free flow from the Ac RUPV to the SVC is preserved.

open-cell "hybrid stent" consisting of a partially covered and partially uncovered stent (Zephyr; Sahajanand Laser Technology), which is similar to the Optimus Stent (AndraTec GmbH).[11] In addition, they introduce a new technique that refines the approach to some of the more challenging patients. Avoiding a high accessory, nondivertible pulmonary vein while ensuring the covered portion of the stent is sufficiently high to create a seal may be challenging. If the covered portion of the stent is too caudal, there may be a shunt over the top of the covering into the superior vena cava (SVC), and if the stent is implanted too high, the accessory pulmonary vein may be obstructed. Many of these high accessory veins are very small and do not drain a substantial portion of the right lung; inadvertent or deliberate occlusion of these is usually uneventful. Nevertheless, there is 1 report of blockage of such a vein causing resistant hemoptysis requiring a partial lobectomy, so an approach avoiding pulmonary vein occlusion is welcomed.[1,6] In patients with a short SVC landing zone, stability of the stent may require the cranial end of the stent to be flared into the azygos or innominate veins. While occlusion of the azygos vein is not considered to be of importance—it is regularly ligated during congenital cardiac surgery—the same cannot be applied to the innominate vein. Innominate veins blocked by the stent covering have required access from the left subclavian vein for needle puncture and balloon dilation through the struts.[1,5]

The technique proposed by Sivakumar et al[12] requires a second guide wire to be placed in the high pulmonary vein or innominate vein, which is then passed through a guide catheter placed through the most caudal uncovered zig of the hybrid stent alongside the implantation balloon. This allows very accurate positioning of the covered stent portion immediately below the orifice of the vein and avoids occluding it. The 2 "hybrid" stents that are available to some (Optimus and Zephyr) are open-cell stents so that trapping of the second guide wire/guide catheter assembly appears to be low risk but is a potential concern. It is possible that using a small peripheral artery balloon rather than a guide catheter would mitigate against this because if there was trapping of the second guide wire by the stent, the struts could be dilated without needing an exchange. Closed-cell stents may be even more at risk from this technique.

We have previously mounted a covered and uncovered stent simultaneously on 1 balloon to create a hybrid stent[1]; however, accurate placement so that the covering is well-opposed to the SVC above the defect and immediately below the orifice of the additional pulmonary vein is challenging. The exact site of entrance of the vein into the SVC is not always clear, and keeping the stent at that level as the stent shortens during deployment is imprecise. On occasion, we have had to add a third covered stent to deal with a residual shunt at the cranial end of the covered stent in this situation. The approach described by Sivakumar et al[12] can be modified and applied to a single covered stent, allowing more accurate placement of the stent in this situation (Figure 1). A covered stent (CCP; Numed) is mounted on both the appropriate dilating balloon as well as a small side-by-side peripheral artery balloon that extends beyond the cranial end of the covered stent over a second guide wire in the high accessory vein (Figure 1C-E). This allows the cranial end of the covered stent to be accurately placed at the inferior margin of the accessory pulmonary vein and avoid a shunt over the top of the covered stent. A second bare stent is then used to anchor the covered stent after removing the balloon and guide wire from the accessory pulmonary vein (Figure 1F). This is a more cumbersome approach than that used by Sivakumar et al,[12] but until hybrid stents are reliably available, this appears to be a reasonable compromise. In the example shown in this study, the anchoring bare stent compressed the orifice of the accessory vein, which needed to be dilated through the struts of the bare stent to reestablish flow (Figure 1G and H).

CSC for SVASD continues to be a challenging procedure due to the wide variation in pulmonary venous anatomy. Careful assessment using cross-sectional imaging with 3D reconstruction, virtual reality modeling, and even 3D printed heart models may all be needed.[4,14] Intraprocedural transesophageal echocardiography, balloon occlusion testing with pressure measurements, angiography, and color-flow and pulse-wave Doppler are also helpful when deciding whether to proceed.[15] Once the decision to proceed has been made, achieving adequate cranial anchorage in the SVC, avoidance of pulmonary venous pathway obstruction, and a seal to abolish the shunt are requirements for an optimal result. Since its inception, the procedure has been gradually refined so that a comfortable workflow has been established in many centers. Additional developments such as the hybrid stent and delivery over 2 guide wires technique in the accompanying article, while only applicable to a proportion of patients, are helping to drive the procedure forward.

Declaration of competing interest

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