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Transcatheter Closure of Superior Sinus Venosus Atrial Septal Defect With Covered Stent Using a Suture-Assisted Deployment Technique

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Abstract

Background: Surgical repair has been the standard therapy for superior sinusvenosus atrial septal defect with associated anomalous pulmonary venous drainage. Transcatheter closure using covered stents has been introduced more recently as a less invasive alternative, but early experience demonstrated significant risks, particularly related to the inability to control precise stent positioning and the danger of migration or pulmonary venous obstruction. A novel suture-assisted deployment technique has been proposed to overcome these limitations.[1]

Objectives: To report our initial two cases of superior sinus venosus atrial septal defect closure using the suture-assisted covered stent technique and pulmonary vein measurement using a catheter across the defect, thus avoiding the transeptal puncture.

Methods: Three patients were elected for the technique; one was deemed not suitable due to high pulmonary venous pressure with balloon occlusion test. The procedures employed bilateral femoral venous access and right internal jugular access with establishment of a veno-venous femoro-jugular rail. Covered CP stent was prepared with a tethering suture and deployed using a two-balloon strategy (initial positioning balloon followed by definitive expansion balloon).

Results: Both cases were technically successful, with accurate stent positioning, complete defect exclusion, and unobstructed pulmonary venous drainage. No procedural or early complications occurred. Early follow-up by echocardiography and X-ray confirmed stable stent position and preserved pulmonary venous flow and complete closure of the SVASD.

Conclusion: The simplified technique using the suture-assisted stent and pulmonary vein measurement using direct catheter across the defect, thereby, avoiding the transeptal puncture appears feasible and safe. It allows controlled deployment and reduces the risk of malposition and inadvertently stent embolization. Larger series and longer follow-up are needed to establish long-term outcomes.

Key Words: Transcather Closure, Superior Sinus Venosus Atrial Septal Defect, Covered Stent, Suture-Assisted Deployment Technique, Pulmonary Venous Drainage

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Introduction

Superior sinus venosus atrial septal defects (SVASDs) are an uncommon subtype of ASD and are characteristically associated with partial anomalous pulmonary venous connection (PAPVC), most often involving right upper pulmonary venous drainage to the SVC. Surgical repair remains the gold standard with excellent outcomes, but it requires cardiopulmonary bypass and sternotomy and can be complicated by sinus node dysfunction, SVC obstruction.[2]

In the past decade, a transcatheter strategy using long covered stents has emerged as a less-invasive alternative that excludes interatrial communication while maintaining unobstructed pulmonary venous return to the left atrium. Early experience highlighted important technical limitations with traditional covered-stent tech-

nical limitations with traditional covered-stent implantation, mainly deployment instability, difficulties achieving precise positioning, and risks of migration, pulmonary venous compromise, or residual shunt and often prompting adjunctive trans-septal evaluation of pulmonary venous patency.[3,4] To overcome these limitations, Hejazi and colleagues, described the temporary suture-holding technique, which enables external control of the covered stent during deployment and thereby enhances accuracy and stability.[1]

Here, we report our center's experience of superior SVASD closure with PAPVC using suture-assisted covered stent technique and pulmonary vein measurement using a catheter across the defect, thus avoiding the transeptal puncture. This highlights procedural details, early outcomes, and technical considerations.

Clinical Case and Procedure

Three male patients, aged 10 years (55.7 kg), 5 years (25.5 kg) and 10 years (50 kg), the third case was aborted due to high pulmonary venous pressure after balloon testing, the other two underwent transcather superior sinus venosus atrial septal defect (SVASD). All demonstrated right heart dilation on echocardiography. Advanced imaging confirmed the diagnosis. They underwent cardiac MRI which showed significant Qp:Qs shunt. Then they underwent CT angiography to delineate the anatomy and the partial anomalous veins. In both cases, anomalous drainage of the right upper pulmonary vein into the superior vena cava was identified (Figure 1).

They subsequently underwent transcatheter closure of the SVASD using the temporary suture-holding technique originally introduced by Hejazi and colleagues, with pulmonary vein measurement using a catheter across the defect, thus avoiding the transeptal puncture.[1] The procedural steps are outlined below.

All procedures were performed under general anesthesia with transesophageal echocardiographic guidance. Vascular access was obtained via bilateral femoral veins and the right internal jugular vein. A femoral–jugular rail was established by advancing a catheter and wire from the femoral vein into the SVC and snaring the wire from the right internal jugular vein.

The procedure was initiated by advancing a non-compliant balloon across the superior sinus venosus defect and inflating it under fluoroscopic and transesophageal echocardiographic (TEE) guidance. A second catheter, an end- and side-hole 5-Fr Judkins, was introduced from the left femoral vein to monitor pulmonary veins, allowing selective injections and continuous pressure monitoring. While using a non-compliant balloon to occlude the SVC. This strategy ensured that balloon inflation effectively occluded the interatrial shunt while confirming that pulmonary venous drainage remained unobstructed and redirected into the left atrium without the need for transeptal puncture. Only after these preliminary assessments confirmed suitability for transcatheter closure was the covered stent prepared for deployment (Figure 2).

Then, a 10-zig, 6-cm long-covered CP stent was manually crimped onto a non-compliant Atlas balloon with a temporary suture looping through one of its proximal struts. The stent was advanced over a through-and-through femoro-jugular rail and deliberately undersized compared with the final superior vena cava (SVC) diameter. Inflation of this "positioning

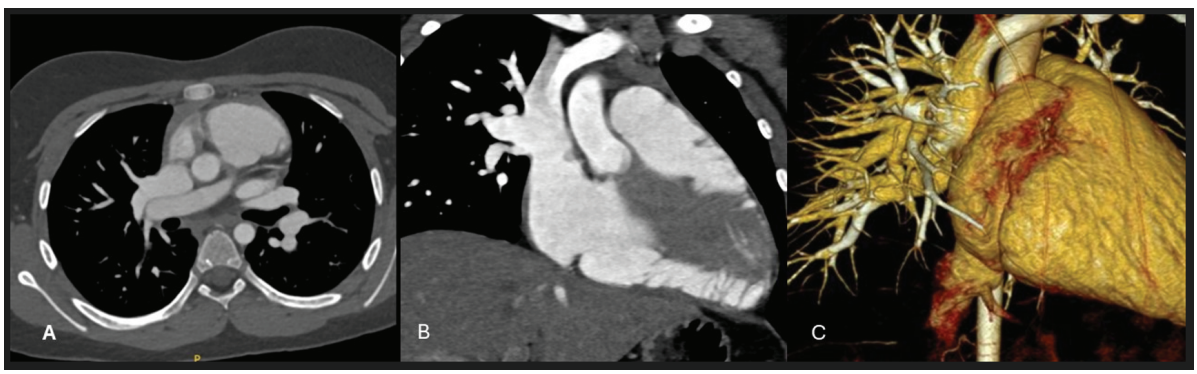

Figure 1: CT angiography **A** Axial view **B** Coronal view, **C** 3D reconstructed image. All demonstrate Anomalous connections between the right upper and middle pulmonary veins to SVC.

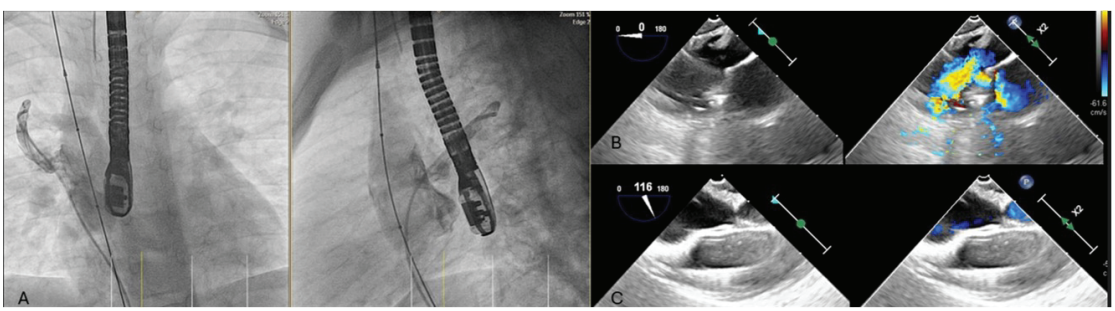

Figure 2: **A** An AP and Lateral View fluoroscopy showing direct catheter in the RUPV injection while inflating the non-compliant balloon and showing the RUPV drain redirected to LA. **B** TEE color compare view showing the Sinus venosus defect, **C** Showing closure of shunt after balloon inflation

balloon" partially expanded the stent, creating sufficient friction to maintain its location while still permitting controlled adjustments along the rail, as previously described.[1]

Due to the suture being exited through the right internal jugular sheath, gentle external traction allowed fine repositioning of the proximal stent edge either cranially or caudally. This maneuver was particularly valuable early migration toward the right atrium, as tension on the suture could reposition the stent more securely within the SVC, addressing one of the principal limitations of earlier covered-stent techniques.

During this stage, the covered stent was only partially expanded on the balloon and remained fully controlled by the external suture. This configuration left sufficient space within the SVC to accommodate the end- and side-hole Judkin catheter alongside the balloon shaft, permitting continuous pressure monitoring and selective angiography from the right upper pulmonary vein. In this way, we could confirm that the partially deployed stent did not compromise pulmonary venous return, thereby ensuring safety during positioning and eliminating the need for transseptal access (Figure 3).

Once angiography and transesophageal echocardiography (TEE) confirmed appropriate positioning and unobstructed pulmonary venous return. A larger high-pressure non-complaint balloon, sized to the full diameter of the SVC, was advanced over the rail and inflated to fully expand the covered stent and achieve circumferential apposition. With the stent stabilized by the expanded balloon, the temporary suture was withdrawn by pulling one free end until it slid out of the strut. Because the suture was looped rather than knotted, removal was straightforward and did not disturb the stent's position. To optimize proximal anchoring, we used an Andra XXL bare Metal stent (48 mm) in the second patient, and was deployed superiorly, overlapping with the covered stent. Then, the balloon inflations (Z-Med 26 × 40 mm) ensured complete stabilization. Selective injections into the RUPV after deployment demonstrated unobstructed drainage into the left atrium with no residual shunt.

Final angiography, selective pulmonary venous injections, and TEE confirmed complete exclusion of the defect, absence of residual shunt, and stable stent position without pulmonary venous compromise. This technique provided precise intraprocedural control, minimized the risk of migration, and reproduced the strategy originally introduced by Hejazi and colleagues for suture-assisted covered stent deployment (Figure 4).

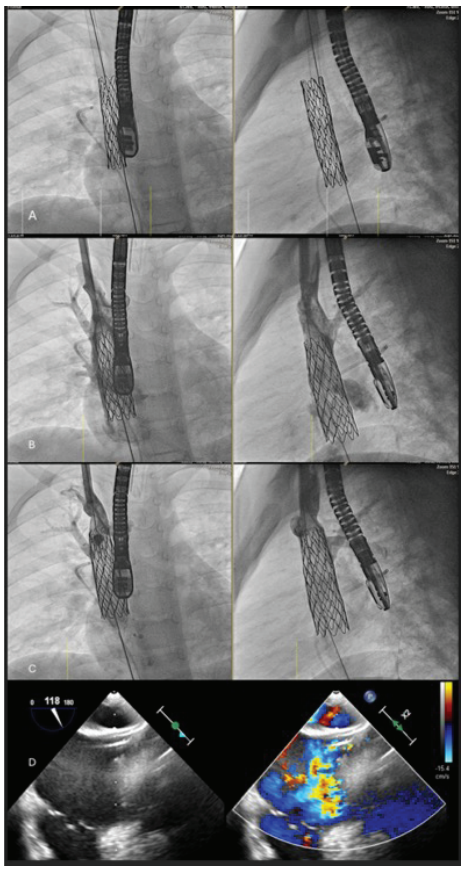

Figure 3: **A** Fluoroscopic AP and lateral view demonstrated the long stent after being partially inflated by the balloon while the other Cather is continually monitoring the pulmonary venous pressure and ready to be used for angiogram injection to delineate the proper position. **B** The angiogram showed unobstructed pulmonary veins. However, the stent was pushed deep into the RA. **C** Angiogram, after pulling the stent up using the suture, showing the stent in a good position above the azygous vein. **D** Continuous TEE monitoring.

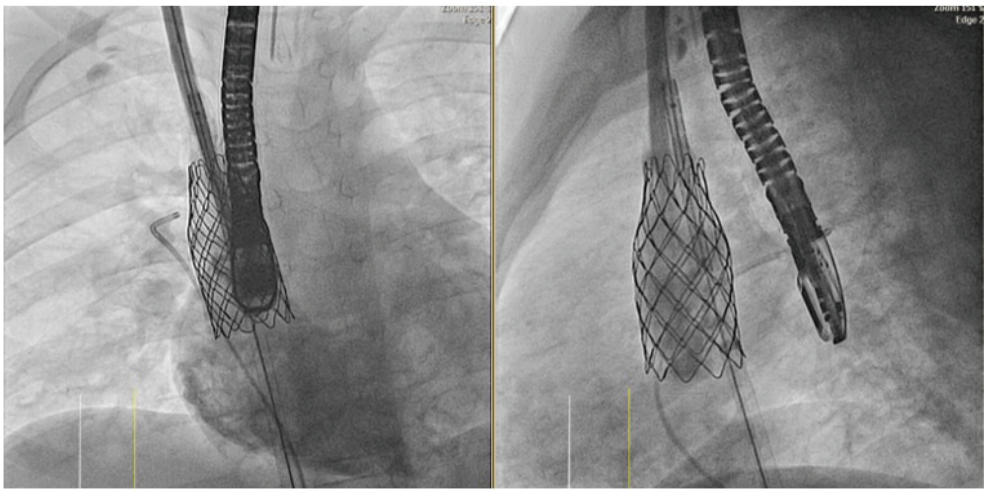

Figure 4: After fully deployed the covered stent and insertion of the uncovered Andra Bare metal stent.

Results

Both procedures were technically successful, with accurate stent positioning and complete exclusion of the sinus venosus defect. Immediate post-deployment angiography and selective right upper pulmonary vein injections confirmed unobstructed pulmonary venous drainage into the left atrium without residual shunting. Transesophageal echocardiography corroborated these findings, demonstrating appropriate stent apposition and redirection of pulmonary venous flow (Figure 5).

Both patients were extubated in the catheterization laboratory and transferred to the ward in stable condition. No periprocedural complications such as arrhythmia, vascular injury, or stent migration were observed. Early follow-up with transthoracic echocardiography showed stable stent position, unobstructed systemic and pulmonary venous return. Chest X-ray showed confirmed stent position (Figure 6).

Discussion

Surgical repair remains the gold standard for superior SVASD with PAPVC, with excellent long-term outcomes. However, it requires cardiopulmonary bypass and carries potential complications including sinus node dysfunction and SVC narrowing. In recent years, transcatheter strategies employing long covered stents have emerged as a promising less-invasive alternative. Early experience highlighted significant technical challenges, particularly the risk of stent migration, difficulty achieving precise deployment, and concerns regarding pulmonary venous obstruction. These limitations frequently necessitated adjunctive trans-septal puncture to monitor pulmonary venous patency.

The temporary suture-holding technique, first described by Hejazi and colleagues, offers a simple but powerful solution to these challenges.[1] By maintaining external control of the proximal stent edge, the operator

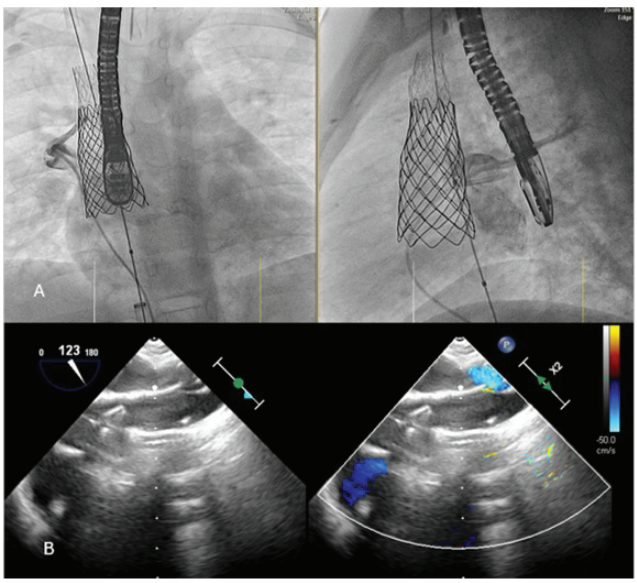

Figure 5: **A** Angiogram in the RUPV showing successful redirection of pulmonary venous flow to the LA. **B** Color Doppler TEE showing no residual sinus venosus shunt.

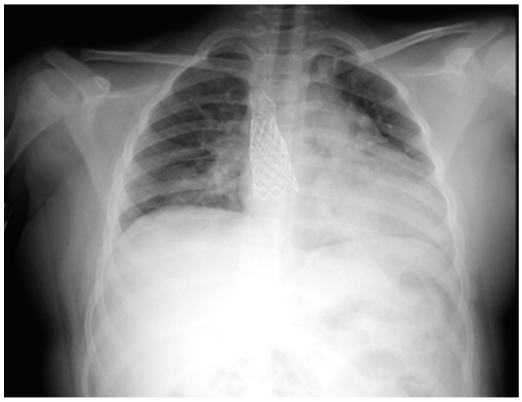

Figure 6: X-ray 24 hours post procedure confirmed stent in position.

can reposition the device during deployment, mitigating the risk of malposition or embolization. In addition, leaving the stent partially expanded while still tethered permits the simultaneous use of a pulmonary venous catheter and the ability of repositioning the stent, ensuring continuous hemodynamic and angiographic assessment without requiring transseptal puncture.

In our experience, this simplified method proved highly effective, allowing controlled and reproducible deployment with stable exclusion of the defect and preservation of pulmonary venous return. The addition of a bare-metal stent proximally in one patient optimized anchoring, illustrating how this approach can be adapted to individual anatomic considerations. Our results are consistent with previously published reports, which demonstrate encouraging procedural success and short-term outcomes.[1] Nevertheless, long-term follow-up is essential to assess stent durability, endothelialization, and the risk of late venous obstruction.

Conclusion

The suture-assisted covered stent technique provides a feasible and safe method for transcatheter closure of superior SVASD with PAPVC. In our two pediatric cases, it allowed accurate deployment, effective exclusion of the defect, and preservation of pulmonary venous drainage without complications. While surgical repair remains the gold standard, this approach may represent a reproducible alternative in carefully selected patients in specialized centers. Larger multicenter experience and longer-term data are required to establish its role in routine practice.

Ethical Approval and Informed Consent

The study was conducted in accordance with the ethical standards of the institutional and national research committee. Approval to use patient data was obtained from the Prince Sultan Cardiac Center, Riyadh, Kingdom of Saudi Arabia. All patients (or their legal guardians, when applicable) provided written informed consent for their clinical information and images to be used for research and publication purposes, with all identifying details removed to ensure confidentiality.

Disclosure Statement

The authors have no conflicts of interests to declare.

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