Innominate vein occlusion by the fabric of covered stent during transcatheter closure of sinus venosus defects – Causes, management, and outcome

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ABSTRACT

Transcatheter sinus venosus defect (SVD) closure with covered stents is emerging as an alternative to surgery. An adequate anchor zone in the superior vena cava is mandatory for the stability of the covered stent to prevent caudal embolization. There is a potential risk of innominate vein occlusion by the fabric of the covered stent in patients with a very short superior caval vein. Three among a total of 105 patients who underwent SVD closure at our institution developed innominate vein occlusion. Predisposing anatomical factors, identification and management of occluded innominate vein, and follow-up outcomes are discussed.

Keywords: Anomalous pulmonary vein drainage, fabric, recanalization, superior vena cava, systemic venous drainage, venous occlusion

INTRODUCTION

The superior vena cava (SVC) form of sinus venosus defect (SVD) is characterized by an interatrial shunt that lies beyond the oval fossa. Deficiency of the tissue between the right upper pulmonary vein (RUPV) and SVC in the developing embryo leads to anomalous drainage of the former into the latter.[1] Despite different modifications, surgical corrections may be complicated by late stenosis of SVC and RUPV, sinus nodal dysfunction, persistent left-to-right shunt from unidentified additional high-draining pulmonary veins, and rare redirection of SVC to the left atrium.[1-3] Transcatheter SVD closure using balloon-expandable covered stents is emerging as a surgical alternative.[4] The bell-bottom shape of the cavo-atrial junction warrants an adequately long anchor zone of at least 2 cm in the SVC to provide stability to the covered stent and prevent its caudal migration and embolization to the right atrium.[5] In patients with short SVC segment between the junction of the two innominate veins and the site of drainage of the RUPV, the fabric from the cranial end of the covered stent may occlude one of the innominate veins.[4-6] Three patients, among a total of 105 patients who underwent nonsurgical SVD closure at our institution, developed this complication during the procedure and were effectively managed in the same sitting. This article describes the anatomical predisposing factors for innominate vein occlusion, its identification and management, as well as the long-term follow-up imaging of these patients.

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CASE REPORTS

Case 1

A 47-year-old female with palpitations and breathlessness on effort was diagnosed to have SVD with mild hyperkinetic pulmonary hypertension and a shunt ratio of 2.3:1. The RUPV drained to a single right SVC as a single trunk above the cavoatrial junction. Computed tomography (CT) showed a short SVC measuring 1.6 cm above the drainage of the RUPV. A pigtail catheter was placed through a transseptal puncture from left femoral venous access in the RUPV for pressure monitoring and angiography. A marker pigtail angiogram from the SVC confirmed a short 1.6 cm anchor zone between the union of the innominate veins and the point of drainage of the RUPV [Figure 1]. Balloon interrogation using a long 24 mm × 8 cm balloon in balloon (BIB) balloon (Numed Inc., Hopkinton, NY) advanced through a Lunderquist wire (Cook Medical, Bloomington, IN) confirmed complete occlusion of the SVD with an unobstructed redirection of the RUPV to the left atrium. Deployment of a 79-mm covered ZephyrXL (Sahajanand Laser Technology, Gujarat, India) across the cavoatrial junction on the same balloon closed the SVD permanently and routed the RUPV to the left atrium. Access to a left jugular vein was obtained because the left innominate vein could not be cannulated from the upper end of the covered stent. An angiogram confirmed occlusion of the vein by the fabric of the covered stent [Figure 2]. Recanalization with a Brockenbrough needle and dilatation with a 12 mm × 4 cm Mustang balloon (Boston Scientific, Marlborough, MA) restored the venous return on a jugular venogram. After 3 months, CT showed a patent innominate vein, complete SVD closure, and unobstructed RUPV redirection to the left atrium [Figure 3]. Oral anticoagulation after the procedure was downgraded to aspirin after the CT imaging.

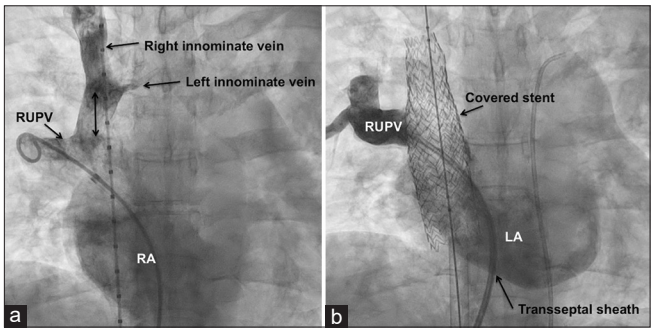

Figure 1: Right innominate vein angiogram with a marker pigtail and a simultaneous right upper pulmonary vein (RUPV) injection through another pigtail catheter (a) advanced through a transseptal sheath demonstrate a short anchor zone (double arrow) measuring 1.6 cm between the union of the innominate veins and the region of drainage of the RUPV. Following a covered stent deployment, RUPV angiogram (b) shows its redirection to the left atrium and absence of filling of the right atrium. RUPV: Right upper pulmonary vein, LA: Left atrium, RA: Right atrium

Case 2

A 22-year-old female was diagnosed with SVD when a chest X-ray showed cardiomegaly during a preemployment health screen. The echocardiogram showed two additional oval fossa defects, right heart dilation, and normal pulmonary artery pressures. CT showed a short SVC anchor zone measuring 1.2 cm [Figure 4]. Cavoatrial junction was interrogated using a 24 mm × 7.5 cm BIB balloon. Two separate left femoral venous accesses were used to individually occlude the two oval fossa defects with separate sizing balloons.[7] RUPV angiogram with pigtail catheter advanced through one of the left femoral venous sheaths showed complete elimination of the interatrial shunt and unobstructed redirection of the RUPV to the left atrium [Figure 5]. The pressures in RUPV were 10 mmHg, similar to the left atrial pressures. The two oval fossa defects were closed with two 14 mm Amplatzer septal occluders (Abbott Inc., Plymouth, MN). The SVD was closed using a long 79 mm covered Zephyr stent on the same balloon under transesophageal echocardiographic guidance. Failure to cannulate the left innominate vein led to the detection of its occlusion by the fabric of the covered stent after jugular venous access. Recanalization with a Brockenbrough needle and balloon dilatation of the struts resumed left innominate

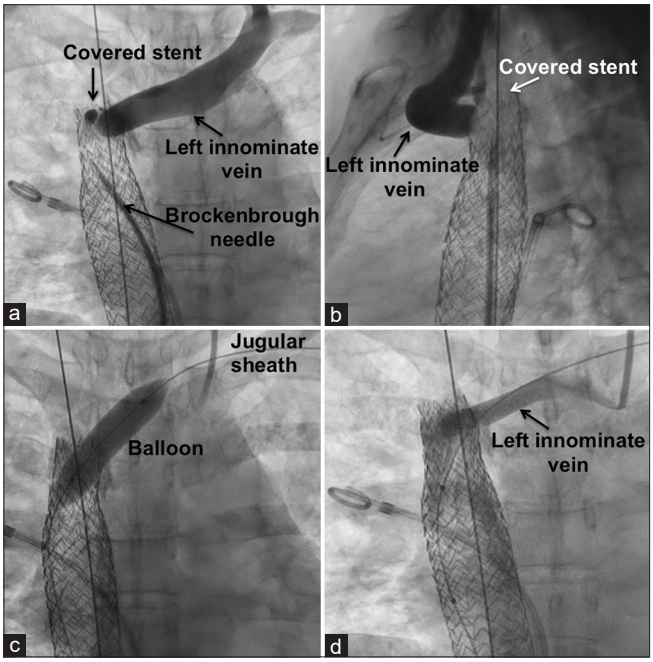

Figure 2: Left innominate vein angiogram through a left jugular sheath in the anteroposterior (a) and lateral views (b) shows its occlusion by the fabric at the upper end of the covered stent. After recanalization with a Brockenbrough needle and stent strut dilatation with a balloon (c), the left innominate venous drainage is restored (d)

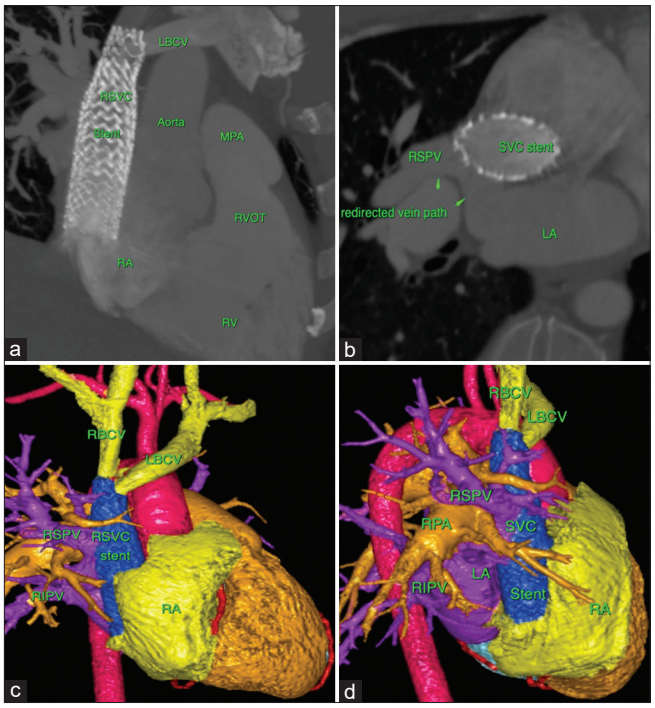

Figure 3: Computed tomographic reconstructed image 3 months after the procedure in modified sagittal (a) and modified axial (b) plane shows unobstructed drainage of left brachiocephalic vein to the right superior vena cava and finally to the right atrium, right ventricle, right ventricle outflow and main pulmonary artery (MPA) through the stent. The right superior pulmonary vein is redirected behind the covered stent to the left atrium. Volume-rendered images from the right anterior (c) and right lateral (d) views show a three-dimensional anatomy following the intervention. LBCV: Left brachiocephalic vein, RSVC: Right superior vena cava, RSPV: Right superior pulmonary vein, RV: Right ventricle, LA: Left atrium, RA: Right atrium, SVC: Superior vena cava, RBCV: Right brachiocephalic vein, RIPV: Right inferior pulmonary vein, RPA: Right pulmonary artery, RVOT: Right ventricle outflow, MPA: Main pulmonary artery

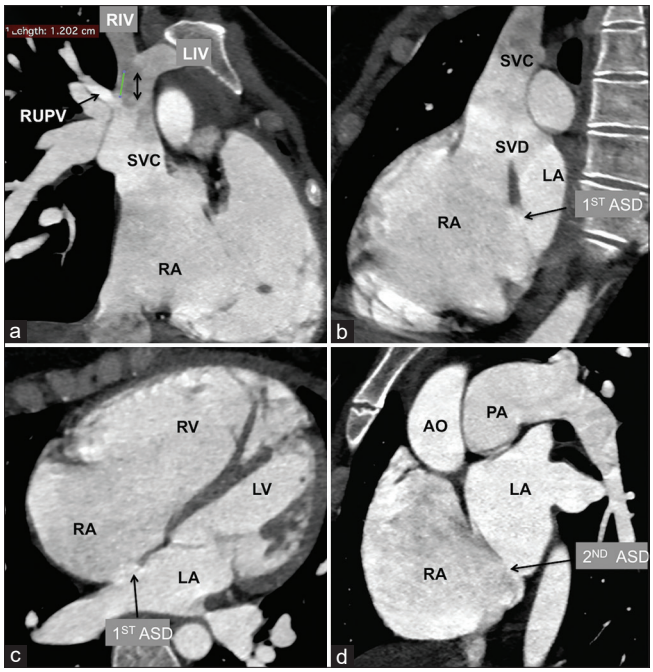

Figure 4: Computed tomographic modified coronal (a), sagittal (b), axial (c), and oblique (d) images demonstrate superior vena cava straddling of the sinus venous defect. The anchoring zone between the union of the right innominate veins and left innominate veins and the drainage of the right upper pulmonary vein is short, measuring 1.2 cm (double arrow). The right atrial and right ventricular dilation compared to the left atrium and left ventricle are additionally contributed by shunt through two atrial septal defects, one located in the middle of the oval fossa and other inferiorly. RUPV: Right upper pulmonary vein, LV: Left ventricle, RV: Right ventricle, LA: Left atrium, RA: Right atrium, SVC: Superior vena cava, LIV: Left innominate vein, RIV: Right innominate vein, SVD: Sinus venous defect, PA: Pulmonary artery, AO: Aorta, ASD: Atrial septal defect

venous return to the SVC. The patient was planned for a monitored warfarin therapy for 6 months.

Case 3

A 54-year-old male with SVD, large left-to-right shunt, mild hyperkinetic pulmonary hypertension, and a short SVC anchor zone measuring 1.6 cm developed left innominate vein occlusion after SVD closure using two overlapped 57 mm covered Andrastents XXL (Andramed, Reutlingen, Germany) 5 years ago [Figure 6]. This was published earlier in our initial experience.[4] He received dual antiplatelet therapy for 1 year. On a 5-year follow-up, the innominate vein flows were normal, with complete closure of the SVD and unobstructed RUPV drainage to the left atrium.

DISCUSSION

Nonsurgical correction of SVD with anomalously draining RUPV using balloon-expandable covered stents is increasingly adopted globally due to patient preference and short recovery time, especially in adults with high surgical risks.[4,8] A short anchor zone <2 cm in the SVC between the union of the innominate veins and the RUPV may reduce the stability of the stent, given the variable diameters of the cavoatrial junction with a narrow upper end and wide lower atrial end.[6]

Two different methods suggested to avoid caudal stent migration and embolization include using an anchoring stitch for the upper end of the covered stent from jugular vein access or suturing two stents together before deployment.[9] An anchor zone of at least 2 cm in the SVC is essential for the stability of the covered stent.[5,6]

When preprocedural CT images showed a short anchor zone of <2 cm, these patients were at high risk of developing left innominate vein occlusion if the long Lunderquist wire was parked in the right jugular bulb during the stent deployment. On the contrary, if the guidewire tip was parked in the left brachial vein before expansion of the covered stent, the right innominate vein might get occluded. It was our practice always to use the right jugular bulb to park the tip of the stiff

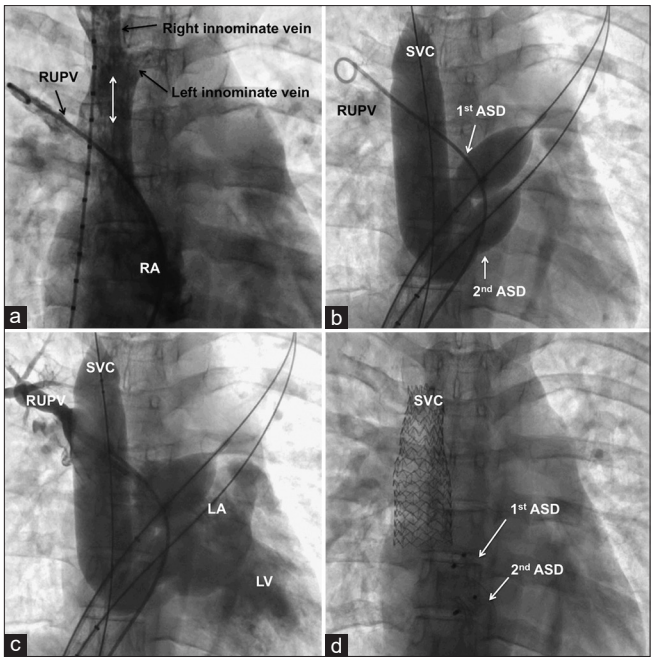

Figure 5: Right innominate vein angiogram through a marker pigtail (a) and right upper pulmonary vein (RUPV) angiogram with another pigtail advanced through one of the oval fossa defect shows a short anchor zone (double arrow) between the union of the innominate veins and RUPV. After inflating a long semi-compliant balloon across the superior vena cava – right atrial junction and additionally occluding the two oval fossa defects with two sizing balloons (b), RUPV angiogram (c) shows its redirection to the left atrium and left ventricle. The sinus venosus defect was closed with a long-covered stent (d), and the oval fossa defects were closed with two occluders. RUPV: Right upper pulmonary vein, LV: Left ventricle, LA: Left atrium, RA: Right atrium, SVC: Superior vena cava, ASD: Atrial septal defect

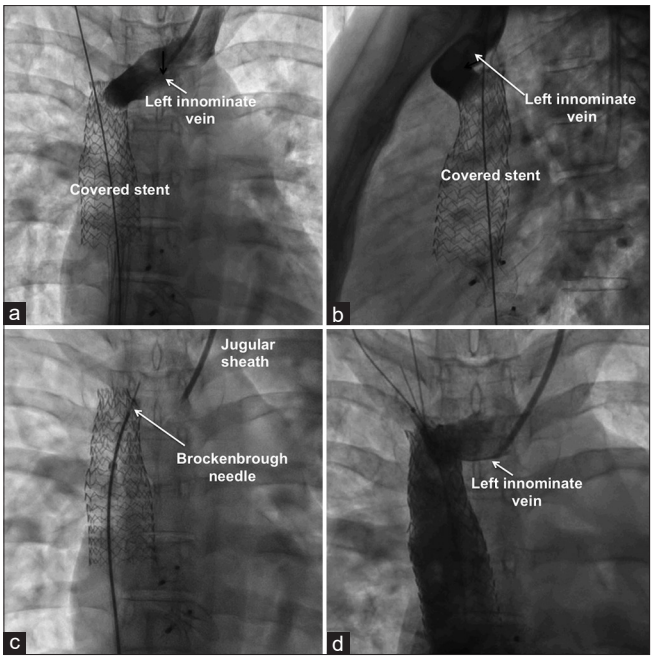

Figure 6: Left jugular sheath angiogram in the antero-posterior (a) and lateral (b) views show occlusion of the left innominate vein by the covered stent. After recanalization with a Brockenbrough needle (c) and strut dilation, left innominate venous drainage (d) was normalized

guidewire in patients with short SVC anchor zones. Ease of obtaining left jugular vein access after recognition of left innominate vein occlusion favored this practice. A curved Brockenbrough needle was used to perforate the fabric at the upper end of the covered stent for recanalizing the left innominate vein. If the right vein was occluded, straightening the curve of the Brockenbrough needle would be required.

Our first patient received dual-antiplatelet therapy following innominate vein recanalization. There were no abnormalities in the venous return to the right atrium after 5 years. However, we initiated warfarin in monitored doses to prevent venous thrombus formation in the latter two patients. The correct anticoagulation-antiplatelet strategy is yet to be established in this relatively new interventional therapy.[10]

A meticulous, systematic documentation of surgical results after SVD correction by different techniques in 109 patients from the Mayo Clinic published in 2005 remains the most quoted literature in this relatively rare interatrial communication.[1] Late complications on follow-up of this cohort included sick sinus syndrome needing pacemaker implantation in six patients, new-onset atrial fibrillation in seven patients, and the presence of small residual interatrial defect <5 mm in 7% of patients. Experience from two later studies showed SVC and RUPV stenosis in up to 10% of patients.[2,3] As transcatheter closure of SVD is emerging as an alternative to surgery, it is mandatory to document all the procedural problems, their solutions, and their long-term follow-up. While the occurrence of innominate vein occlusion was predictable in patients with short SVC anchor zone, recanalization was possible in all patients to achieve their patency even on a longer follow-up duration up to 5 years.

CONCLUSIONS

In patients with short SVC measuring <2 cm in length, innominate vein occlusion was a potential complication after transcatheter closure using balloon-expandable covered stents, occurring in 3% of patients. While a short anchor zone was easily recognized on a prior CT image, a marker pigtail angiogram of the SVC at the start of the intervention should be a mandatory step in every patient to recognize this anatomical variation and anticipate this complication. Recanalization of the innominate vein was promptly achieved using a Brockenbrough needle and stent strut dilation. The innominate vein retained long-term patency after a successful recanalization. Such patients typically needed either dual antiplatelet therapy or oral anticoagulation.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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