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TECHNICAL NOTE

Strategies for the Management of SVC Stent Migration into the Right Atrium

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Abstract
Purpose Stent migration into the right atrium is a potentially fatal complication of stenting in the venous system and is most likely to occur during the treatment of superior vena cava obstruction. Endovascular approaches that can salvage this hazardous situation are described and the keys to successful treatment are highlighted.
Materials and Methods Four different strategies are reviewed: (1) snaring the stent directly, (2) angioplasty balloon-assisted snaring of the stent, (3) guide wire-assisted snaring of the stent, and (4) superior vena cava-to-inferior vena cava bridging stent.
Results These techniques have been employed in the successful management of four cases. No short- or long-term complications as a result of these maneuvers have been identified. Additional treatment of the underlying disease was possible at the same time in each case.
Conclusion We conclude that prompt management of right atrial stent migration is essential and can be successfully achieved by a variety of ''bale-out'' techniques which are within the technical range of most interventional radiologists.

Keywords Foreign body migration · Right atrium management · Superior vena cava · Stent complications

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Introduction

Stent insertion is a common procedure for the treatment of superior vena cava (SVC) obstruction (SVCO). However, migration of the stent into the right atrium is a rare, but potentially fatal, complication. The best method to deal with migration is not yet established. Several endovascular approaches that have proved successful in treating this complication are described.

Technique 1: Snaring the Stent Directly

A patient was referred for a pacemaker. Prior to this procedure a Luminex stent (Bard; Angiomed, Karlsruhe, Germany) had recently been inserted in the right brachiocephalic vein for dialysis catheter-related stenosis. During pacemaker insertion via the right subclavian vein, the stent migrated to the right atrium. The position of the distal tip of the pacemaker guide wire in the IVC prevented further migration across the tricuspid valve. A second guide wire, via the right subclavian vascular sheath, was passed through the stent into the IVC. Further vascular access was achieved via the right common femoral vein (CFV) and the second guide wire withdrawn through the right CFV sheath and exchanged for an 0.018–in. guide wire, thereby securing the stent in situ. A 25-mm Amplatz gooseneck snare (Bard,

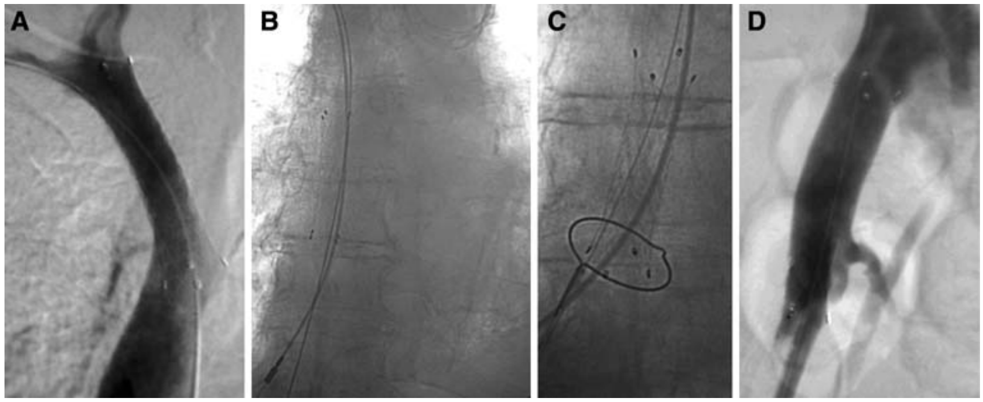

Fig. 1 **A** Venogram demonstrating the right BCV stent and pacemaker wire. **B** Second guide wire passed through the migrated stent into the IVC. **C** Gooseneck snare passed over the second guide wire and end of the stent. **D** Stent repositioned in the right CIV

USA) was passed over the guide wire and used to lasso the stent. The loop of the snare was tightened around the lower end of the stent, compressing and securing it. Once the pacemaker wire was removed the snare stent combination was retrieved from the right atrium (RA) and repositioned in the right common iliac vein (CIV). As the Luminex Nitinol stent cannot be safely be removed via the vascular sheath, the stent was deployed in the right CIV (Fig. 1).

Technique 2: Angioplasty Balloon-Assisted Snaring of the Stent

A 46-year-old woman with metastatic alveolar nasopharyngeal rhabdomyosarcoma developed symptoms of SVCO following chemoradiotherapy. Computed tomography (CT) confirmed mediastinal spread of the disease compressing but not occluding the SVC. Bilateral arm venograms showed a moderate stenosis of the SVC and a further stenosis of the left brachiocephalic vein (BCV) (Fig. 2).

A self-expanding 16-mm Wallstent (Boston Scientific, Galway, Ireland) was placed across the SVC stenosis. During balloon dilation of the stent via the right brachiocephalic vein, the stent migrated centrally into the RA, necessitating retrieval. It did not prove possible to snare the stent directly using technique 1 for two reasons. First, the 25-mm snare kept catching on the edge of the stent, and second, the snare could not be looped over the whole circumference of the stent. Therefore the stent was secured with a guide wire passed via the right internal jugular vein sheath and withdrawn through a 10-Fr sheath in the right CFV. A 16-mm angioplasty balloon (Boston Scientific) was passed over the guide wire, advanced into the stent lumen, and inflated to the nominal diameter of the stent. A 25-mm Amplatz gooseneck snare (Bard) was advanced from the right CFV sheath. The loop of the snare was passed alongside the shaft of the balloon with the loop around the shaft. With the balloon inflated it was possible to manipulate the Amplatz gooseneck snare (Bard) over the

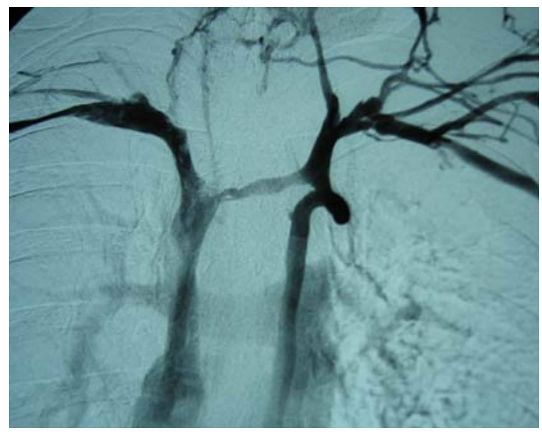

Fig. 2 Bilateral arm venogram showing a moderate stenosis of the SVC and a stenosis of the left BCV

proximal tapered portion of the balloon and then advance the snare loop over the stent without difficulty. The balloon/stent combination was relocated into the right CIV, where it was deployed. The procedure was completed by placing a Wallstent, via the left SCV, across the left brachiocephalic stenosis into the SVC (Fig. 3).

Technique 3: Guide Wire-Assisted Snaring of the Stent

A 35-year-old woman receiving renal dialysis via Tessio catheters developed SVCO. The catheters had previously been inserted via the left brachiocephalic (BCV) with the tips located in the SVC. Bilateral upper limb venograms demonstrated a SVC stenosis.

Prior to stenting of the SVC stenosis the Tesio catheters were removed. Via the RIJV a 14 × 56-mm Wallstent was inserted across the stenosis, with a good angiographic result. During insertion of a new Tessio catheter the Wallstent migrated to the RA. Although the guide wire used to insert the Tessio catheter remained in the lumen of the Wallstent, with its distal extent in the IVC, the stent was definitively secured with a further pull through guide wire inserted from the RIJV, passed through the stent, and withdrawn via a right CFV vascular sheath. Multiple attempts were made to snare the Wallstent directly using an Amplatz gooseneck snare (Bard) as described in Technique 1. However, while the snare captured the Wallstent it disengaged each time an attempt was made to withdraw stent. A third guide wire was passed from the right groin through the lumen of the stent. Further vascular access was obtained via the left CFV and a gooseneck snare was passed alongside the exterior of the stent and used to capture the guide wire as it exited the cranial end of the stent. The wire/stent/snare combination was pulled inferiorly and removed via the right CFV vascular sheath. A 16 × 90-mm Memotherm (Bard) stent was subsequently placed from the SVC to the IVC across the SVC stenosis and RA, and the SVC obstruction was relieved (Fig. 4).

Technique 4: Bridging Stent of the SVC to the IVC

An 83-year-old female presented with a 6.5-cm RUL mass, SVCO, which was found later to be a small cell carcinoma on pleural biopsy. A CT and superior vena cavography demonstrated a severe mid-SVC stenosis (Figs. 5 and 6).

A 14 × 40-mm SMART stent (Cordis, Johnson & Johnson, USA) was deployed across the lesion from a RIJV approach over a wire extended into the IVC. During deployment the stent migrated centrally into the RA but was still restrained by the wire. A right common femoral vein puncture was performed and a second guide wire was negotiated through the stent into the right subclavian vein, further securing the stent. A longer, 14 × 80-mm SMART stent was deployed from the groin access across the stenosis and overlapping the cranial end of the migrated stent located in the distal SVC, thereby fixing the mobile

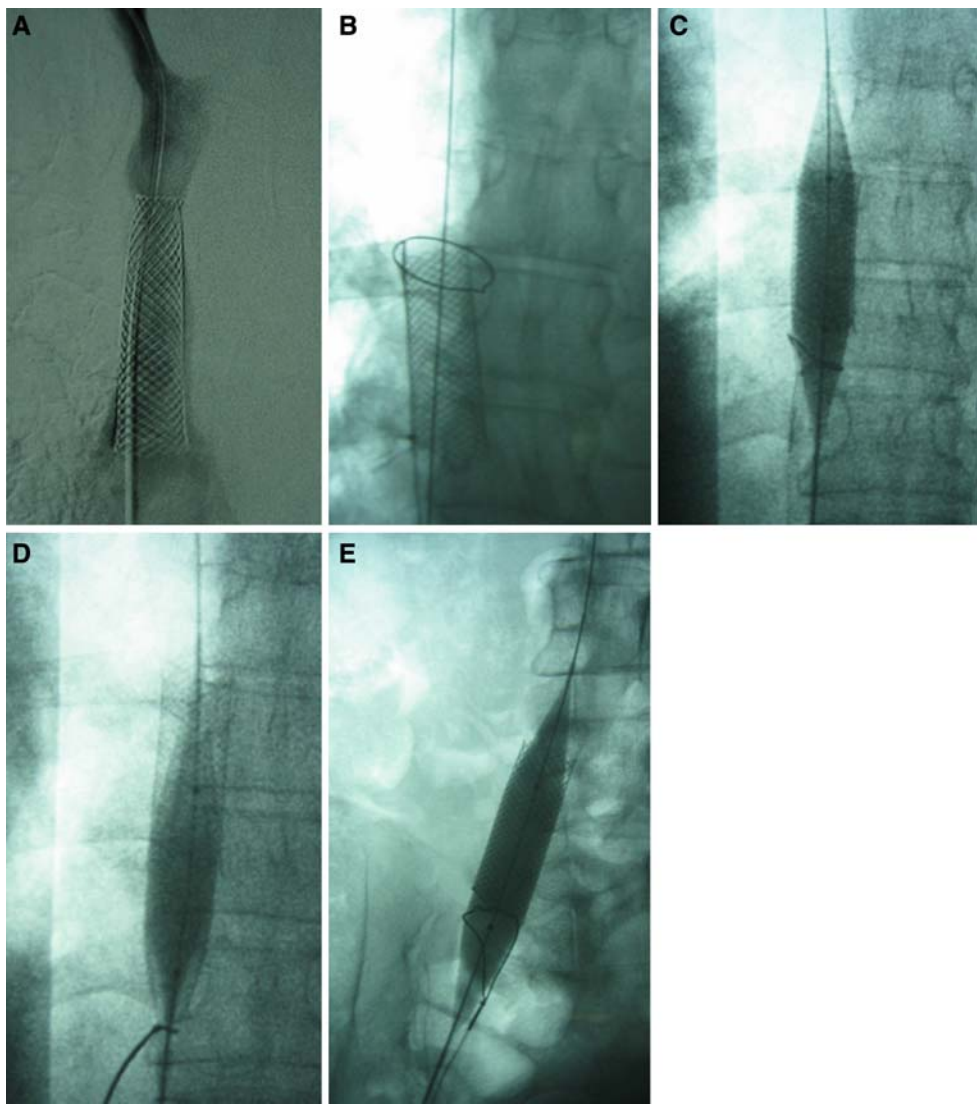

Fig. 3 **A** Arm venogram showing SVC stent across the stenosis. **B** Unsuccessful attempt to snare the stent directly. **C** Angioplasty-assisted snaring of the stent. **D** Closed loop of the snare around the stent and balloon guide wire. **E** Balloon stent combination relocated in the right CIV

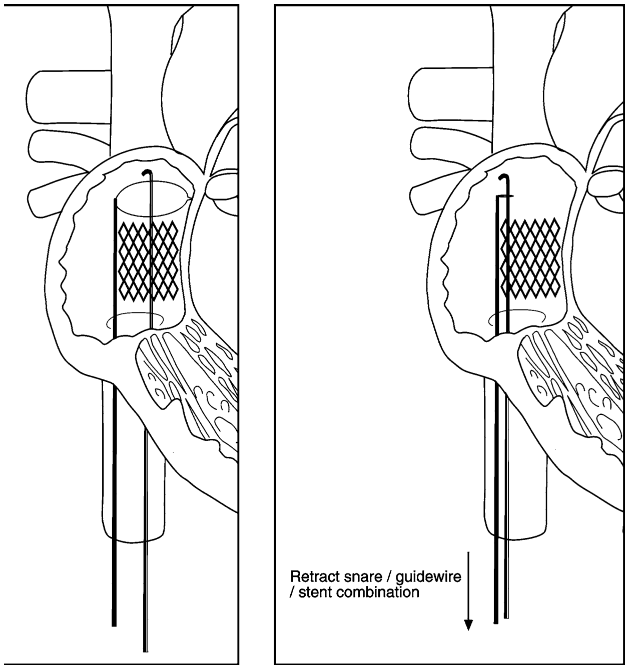

Fig. 4 Illustration demonstrating the capture of the guide wire using a gooseneck snare running along the exterior of the stent, thereby creating a loop around the stent wall and allowing retraction of the guide wire/stent/snare combination

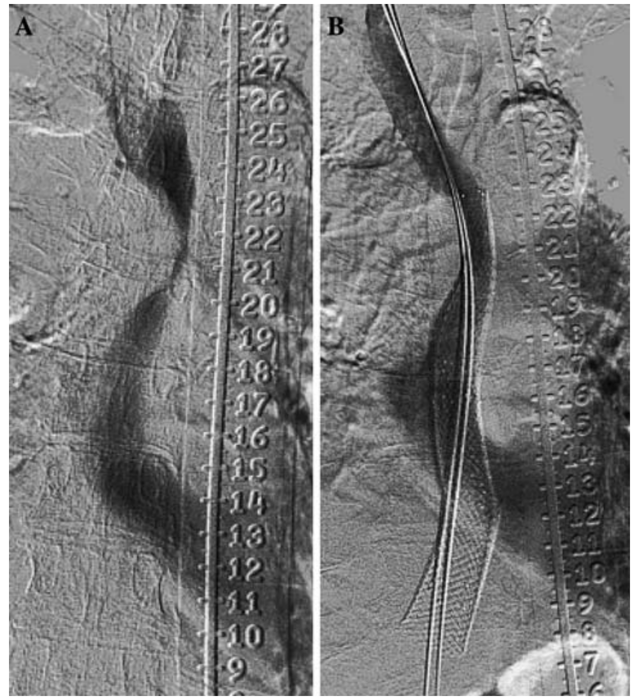

Fig. 6 **A** Arm venogram demonstrating a severe stenosis of the SVC. **B** Venogram showing pull-through guide wire and bridging stents from SVC to IVC following stent migration

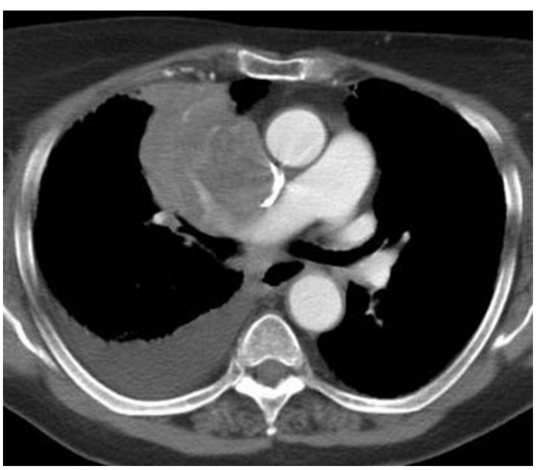

Fig. 5 Contrast-enhanced CT demonstrating a mediastinal soft tissue mass obstructing the SVC and coexistent right pleural effusion

stent. A further 18 × 40-mm Wallstent (Boston Scientific) was deployed from the RIJV and overlapping the caudal end of the migrated stent with the distal extent of this stent located in the IVC. However, with each cardiac cycle there was progressive separation of the migrated stent and the IVC stent, and as a result a further 14 × 60-mm SMART stent was deployed via the RCFV across the lower SVC and IVC segments. Completion venography was satisfactory and no further intervention required (Fig. 6). The patient died 27 days later from bronchopneumonia, with no further stent-related complications.

Discussion

Primary endovascular stenting of symptomatic SVC stenosis or occlusion due to malignancy is now widely cited as the treatment of first choice, with subsequent adjunctive chemo radiotherapy where appropriate. Long-term primary patency rates of between 77% and 85% and secondary patency rates of between 85% and 91% [1–4] have been reported.

In a review of the literature from 1992 to 2001 and 841 cases of SVC stent placement, Martin et al. showed the technical complication rate to be 3.9% and the secondary complication rate to be 9.9%. Migration of SVC stents is uncommon, occurring in approximately 2% of cases [5]. While stent migration to the RA is very uncommon, it requires prompt and effective management to prevent potentially life-threatening sequelae, which include cardiac conduction abnormalities, valvular damage, endocarditis, cardiac tamponade, and cardiac perforation [5–7].

Predisposing factors for stent migration in the setting of SVCO include

(a) poor choice of lesion, with stenting of nonsignificant stenoses which might not be narrow enough to provide purchase for the stent;
(b) inadequate oversizing of the stent;
(c) inaccurate positioning of the stent within the lesion, with subsequent shortening and migration;
(d) central migration of the stent due to the effect of cardiac motion;
(e) inaccurate vessel measurement;
(f) cases in which the disease can be expected to resolve with treatment, for example, Hodgkin's lymphoma;
(g) stent deployment system—some designs of self-expanding stents tend to ''jump'' forwards during latter stages of deployment as they are not anchored to the delivery shaft; and
(h) delivery route—from the common femoral approach, any stent ''jump'' will be away from the RA.

These factors should be considered prior to stent deployment to minimize the risks of stent migration.

The current experience with stenting in SVCO has largely been with three makes of stent: the Gianturco Z-stent (Cook, Bloomington, IN, USA), the Wallstent (Boston Scientific), and the Palmaz stent (Cordis, Miami, FL, USA). The use of the Gianturco Z-stent has recently declined and newer stents such as the Memotherm (Bard, Angiomed), Luminex (Bard, Angiomed), and Smart (Cordis, Johnson & Johnson, USA) have been introduced. Most reported experience with SVC stenting has been with the Wallstent.

At present there appears to be no significance difference in the published outcomes with the Gianturco Z-stent, Palmaz stent, and Wallstent [8] However, many authors prefer the use of self-expandable stents rather than balloon-mounted stents in the venous system because they have a larger diameter, are more flexible, and have intrinsic radial expansive force and thus seem more suitable to the presence of respiratory movements and cardiac movements, with less risk of migration [9]. However, the greater degree of axial shortening with some self-expanding stents, especially the Wallstent, prevents the position of the stent ends to be as accurately predicted when fully expanded. In turn this can lead to initial malposition and a higher risk of stent migration and uncovering of the lesion. At full expansion shortening of up to 50% may occur. However, in reality this rarely occurs and stent shortening is of the order of 25%–30% [10]. Furthermore, there is minimal shortening during deployment of the Memotherm, Luminex, and Smart stents.

The selection of stent width is estimated by vessel measurement on initial cavography, although recent computer software packages have enabled more accurate measurement and most interventionalists recommend deployment of an oversized stent graft with a diameter of between 18 and 22 mm.

Regarding the selection of a stent length, longer stents are much less likely to migrate than short stents. In the CIRSE quality assurance guidelines for SVC stenting in malignant disease, Uberoi suggests the use of a stent length which will cover the occlusion with at least 10 mm free both proximal and distal to the lesion [8]. Short stents may be squeezed by the lesion if they are deployed asymmetrically across the lesion. When deploying the stent, more of the stent should be positioned above the lesion than below it, which will reduce the risk of distal migration. In broad terms, 60% of the stent should be located above the lesion, extending into the BCV where necessary, and 40% below the lesion. This will permit long segment fixation to the vessel wall.

There is little agreement on the place of balloon dilation either before or after deployment of the stent. Dondelinger et al. advocate the use of routine angioplasty prior to stent insertion: to localize the stenosis more accurately, to identify and mark by fluoroscopy the location of the balloon waist, and to estimate the length and severity of the stricture [11]. Many interventionalists prefer to dilate the stent after deployment, as this assists the stent to expand to a greater diameter more quickly than by the stent's inherent radial force alone. A series using Wallstents in SVCO by Dyet et al. found it necessary to perform angioplasty following the procedure in 12 of 17 patients [12].

However, Hochrein et al. recommend not fully dilating the stent in the area of tightest obstruction and attempting to leave both ends flared with a slight ''waist'' in the center to help ensure against stent migration [13]. This flaring also allows the sharp filaments of the central end of the stent to become slightly embedded in the vein wall [14], however, the risk of perforation of the SVC, aorta, or pericardium should be borne in mind. Our practice is to perform balloon dilation after stent deployment with the awareness that balloon dilation may occasionally promote stent migration.

Before the introduction of minimally invasive salvage techniques, the migration of a device such as a stent into the heart necessitated open heart surgery and accompanying cardiopulmonary bypass, with the obvious complications in terms of morbidity and mortality. This major intervention has been superseded by endovascular methods.

Several options exist for the interventional radiologist when faced with a migrated stent in the RA. The techniques described in the above cases should be tailored to individual patients. Slonim et al. report the percutaneous management of 27 misplaced or migrated endovascular stents, 17 of which were in the venous system [15]. They suggested that Palmaz stents should be managed by using a balloon catheter to reposition and deploy the stent in an appropriate-caliber vessel, usually the common iliac vein. This technique is usually undesirable in the case of migrated Wallstents because the stent is self-expanding and will assume the nominal diameter if unconstrained, thereby making it difficult to reposition and deploy the stent into a vessel of an appropriate size. Slonim et al. felt that Wallstents should primarily be managed with the use of snare techniques, either the direct snaring technique, the angioplasty balloon-assisted snare technique, or the guide wire-assisted snare, also called the ‘‘double-loop’’ technique. The rigid nature of the Palmaz stent makes the use of snare techniques less effective and potentially hazardous if a deformed stent is moved through the vascular system. Should lassooing the Wallstent with the snare continue to be unsuccessful despite the use of the techniques described above, Slonim et al. suggest that intravascular biopsy forceps can be used to grasp the end of the stent and reposition the stent into a larger-caliber vessel where passing the snare around the exterior of the stent can be achieved. Other adjunctive techniques include the creation of a snare using a guide wire.

Most techniques for salvage of migrated stents involve the use of a snare. The Nitinol Amplatz Gooseneck snare has a traditional right-angled design, with the advantage of increased tensile strength resulting from the continuous length of Nitinol wire used in its construction. Additionally, the Teflon-coated cable permits excellent torque control of the snare itself, which is further enhanced by the torque control of the snare’s guiding catheter [16]. These properties make the snare ideal for foreign body retrieval.

A number of other simple procedures should be remembered to ensure safe retrieval of the migrated stent. First, care should be taken while manipulating the guide wire through the lumen of the stent not to pass it through the interstices, either entangling the wire or further dislodging the stent; this can be confirmed by passing a catheter over the guide wire. Second, as highlighted in the cases above the stent should be adequately secured with a ‘‘pull-through’’ wire system via combined transjugular and transfemoral access. This will prevent further migration of the stent onto the tricuspid valve or into the right ventricle and its pulmonary arterial outflow. Should the situation arise where a stent needs to be removed from the tricuspid valve or right ventricle, Hartnell et al. have suggested using combined fluoroscopic and transesophageal echocardiography to facilitate safe removal. This dual imaging overcomes the problems associated with fluoroscopy during cardiac motion [17]. If the stent enters the right ventricle, biplane fluoroscopy is invaluable and probably essential to facilitate safe retrieval from this location.

Generally self-expanding stents can be withdrawn through the vascular sheath, causing the stent to fold and buckle on itself. If a self-expanding stent cannot be removed through an adequate-caliber vascular sheath, it may be possible to snare the caudal end of the stent from the CFV and the cranial end of the stent from the RIJV vascular sheath and elongate the stent to narrow the caliber sufficiently so that it can be removed safely. If the self-expanding stent still cannot be percutaneously removed, deployment of the stent in the iliac vein is safe and usually without long-term sequelae. By comparison balloon-expandable stents cannot be easily removed and should be redeployed in an appropriate vein, usually the iliac vein.

Conclusion

In summary, migration of metallic stents into the RA is an uncommon but potentially catastrophic complication of SVC stenting. Prompt management is essential. Several techniques are available to capture the stents and relocate them for either removal through a femoral vascular sheath or deployment in the iliac vein. Securing a guide wire through the stent lumen is mandatory to prevent further migration into the right ventricle. Most techniques involve the use of a gooseneck snare, which is an essential interventional tool for any department undertaking venous stenting. All of the aforementioned techniques for salvage of migrated stents are within the technical range of most interventional radiologists.

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