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REVIEW

Techniques for Intravascular Foreign Body Retrieval

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Abstract As endovascular therapies increase in frequency, the incidence of lost or embolized foreign bodies is increasing. The presence of an intravascular foreign body (IFB) is well recognized to have the potential to cause serious complications. IFB can embolize and impact critical sites such as the heart, with subsequent significant morbidity or mortality. Intravascular foreign bodies most commonly result from embolized central line fragments, but they can originate from many sources, both iatrogenic and noniatrogenic. The percutaneous approach in removing an IFB is widely perceived as the best way to retrieve endovascular foreign bodies. This minimally invasive approach has a high success rate with a low associated morbidity, and it avoids the complications related to open surgical approaches. We examined the characteristics, causes, and incidence of endovascular embolizations and reviewed the various described techniques that have been used to facilitate subsequent explantation of such materials.

Keywords Device removal · Endovascular procedures · Foreign bodies · Interventional radiology

Introduction

The intravascular embolization of foreign material is an uncommon occurrence, but with the increasing range of endovascular therapies, the incidence of a lost intravascular foreign body (IFB) is becoming a more frequent clinical problem. The first described fatality directly attributable to a lost migrated IFB occurred in 1954. The case report detailed an intravascular catheter that had been found within a patient's right atrium at autopsy. It was known to have recently migrated from the cubital vein and had caused the patient's death by perforating the heart [1]. In 1964, Thomas et al. [2] reported the first successful percutaneous retrieval of an IFB, where a fragment of broken guide wire was retrieved percutaneously from a patient's right atrium with a rigid bronchoscope forceps through a sheath. The technique was quickly adopted as an alternative to open surgical removal, and a percutaneous approach is now widely accepted as the first-line method for retrieving IFBs.

IFBs can originate form a variety of sources but are usually iatrogenic. Most commonly IFBs are embolized central line fragments, but guide wires, catheter fragments, embolization coils, inferior vena cava filters, coils, cardiac valve fragments, sheaths, pacing wires, occluder devices, and projectile fragments have been described [3–9]. Appropriate knowledge of available equipment and the various techniques, as well as experience, are key factors in achieving a successful outcome. Egglin et al. [10] found that in up to 25 % of cases, more than one retrieval system or technique was needed to achieve successful removal of an IFB.

Here we detail the range of considerations and techniques that may be beneficial in this predicament.

General Considerations

Preventative Measures

Primary prevention is much better than a secondary successful retrieval of a lost IFB. Although not all IFB are

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iatrogenic, catheter or device loss is usually preceded by a number of difficulties running up to the attempt at device delivery or deployment. Poor guide catheter/guide wire support, proximal vessel tortuosity, and vessel calcification are risk factors that can result in device (e.g., stent) loss. Eggebrecht et al. [11] reviewed the results of 2211 consecutive coronary artery stenting procedures (4066 stents) and found a incident rate of stent embolization of 0.9 % per patient (or 0.49 % per stent). They also demonstrated that manually crimped balloon-mounted stents embolize more often than premounted balloon stents—1.04 % vs. 0.24 %, respectively.

A high proportion of lost IFBs result from a technical error on the part of the operator as opposed to equipment failure, although both occur. Catheters are often displaced as a result of the lack of experience of the operator. In our experience, several migrated lines have resulted from tunneled catheters being inappropriately cut by inexperienced staff at the time of attempted line removal. Good training and knowledge of the devices being used are vital to avoid this complication. Good case planning with appropriate equipment in the range of the operator's experience and training will avoid the majority of lost IFBs.

Imaging to Find the Lost IFB

The first crucial step in achieving the successful retrieval of a lost IFB is to obtaining a accurate history, including identifying the object's size, shape, and current location. This is usually done via plain film, fluoroscopy, or both. Catheter fragments are generally poorly visible fluoroscopically because they are small and are made of material that attenuates x-rays poorly. Overlying tissues and movement-related artefacts (e.g., cardiac motion) further reduce fluoroscopic image clarity. Increasing the pulse/frame rate can help, but at the cost of increased patient exposure to radiation. Our practise is to use computed tomography (CT) as a first-line investigation, but this also comes at the expense of considerable radiation exposure. Catheter fragments may be small, and they are hard to identify even on CT. Magnetic resonance imaging (MRI) has been used judiciously in circumstances where peripheral embolization has occurred and where the foreign body is known to be MRI compatible. In the case of metallic lost IFBs, a gradient echo sequence will result in susceptibility artefact. Many MRIs of IFBs may provide poor visualization of the IFB, and MRIs may be contraindicated in some cases. Ultrasound is feasible but seldom is practicable. Once localized, the interval to subsequent attempted device retrieval should be minimized to mitigate against further device migration.

Preparation for Removal of Devices

Review of previous imaging is essential. Most devices can be removed percutaneously; however, it may not always be appropriate to remove lost IFB endovascularly, and a multidisciplinary team discussion is required (Fig. 1). Liaison with the anesthetic team to ensure an adequate level of patient sedation/anesthesia may be needed. Fully informed consent is vital, and the potential complications should be carefully considered. Risks and potential complications will inevitably depend on the vascular territory involved.

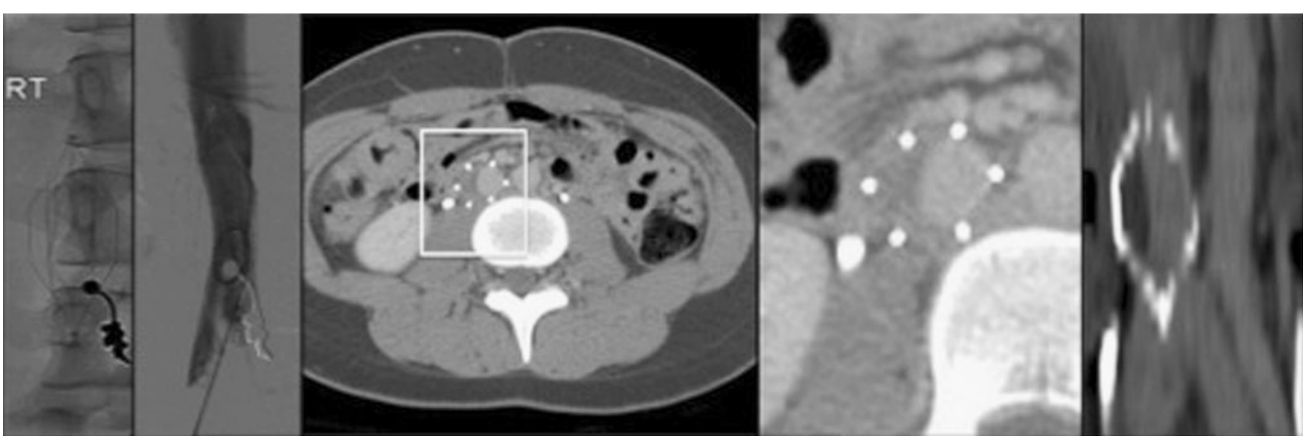

Fig. 1 A 16-year-old girl had an OptEase temporary filter (Cordis) positioned at another institution but attended with us for its removal. **A** Venography revealed exoluminal positioning of some of the device struts. **B** Efforts to collapse the device caused the patient pain. Further efforts at endovascular device extraction were not attempted. **C–E** Subsequent CT (axial and coronal reformats) revealed extensive neointimal hyperplasia. Multidisciplinary team discussion resulted in a decision to advise an open surgical retrieval, primarily as a result of the young age of the patient, making leaving it in situ a suboptimal long-term option

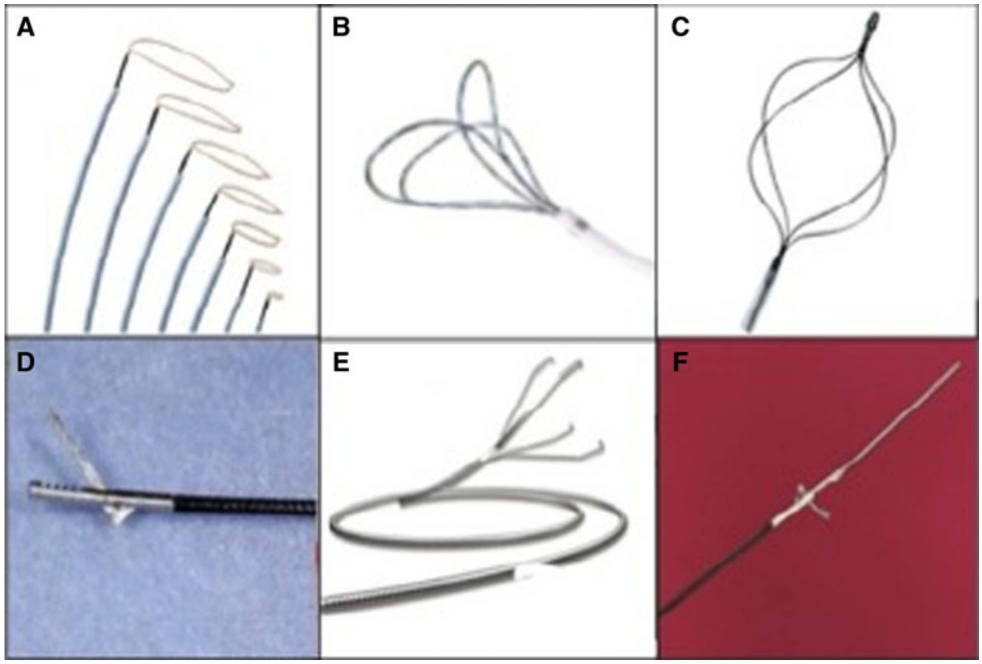

Fig. 2 There are a range of purpose-designed devices now available. **A** Amplatz gooseneck snare (ev3). **B** Trefoil En-Snare (Merit Medical). **C** Dormia baskets. **D**, **E** Alligator retrieval forceps (Cook Medical and ev3). **F** Myocardial biopsy forceps (Cook)

It can be useful to obtain an identical device to work with ex vivo. In a case of a lost catheter fragment that had embolized into right atrium, we successfully snared this via the internal jugular vein; however, the catheter proved too rigid to fold back over on itself (with the snare and the tip of the sheath used as the fulcrum points). Ex vivo testing demonstrated that a significantly larger sheath size was needed to allow the catheter fragment to be folded back over on itself. Ex vivo testing may have highlighted this issue before we commenced the procedure that avoids more complicated maneuvers once the IFB has been captured. It is important to ensure that commonly used devices are available, such as snares, intravascular forceps, large sheaths, guide wires, shaped catheters, and balloons (Fig. 2), and that they are appropriately sized for the vessel they are to be used within. For venous access, we advocate the right femoral vein because it affords ease of access, it is a large-caliber vessel that thus provides easier handling, and it permits good postprocedure compression after removal of potentially large sheaths [10]. If it is anticipated that more than one vascular access point may be required, then optimizing patient position and preparation at the outset of the procedure can save time later. For example, the anesthetists could be asked to avoid using a specific arm for their venous access it if this access point may be required later. Thinking about the route that the IFB will travel will highlight areas of potential difficulty. Rigid IFB can snag at vessel branch points and acute bends, so avoiding these is preferable. Once an item is retrieved, it should be sent for bacteriological evaluation so that subsequent septic complications can be avoided.

Removal Techniques and Devices

Loop Snare

The loop snare is frequently the first choice of device used to attempt removal of an IFB [12, 13]. Over the years, the loop snare has undergone several design iterations. The initial design was a retractable loop that emerged from the end hole of a guide catheter; the loop was thus in the same plane as the catheter. This meant that manipulation of the loop itself was difficult, and consequently device success was lower. Modern designs allow the loop to emerge at 90° to the catheter, which greatly facilitates manipulation of the loop to aid capture of the lost IFB. Nitinol shape memory properties provides wire kink resistance. There are a range of snare devices and sizes, including microsnares (e.g., Radius Medical technologies, MA, USA) measuring 2 mm and in gradations up to 35 mm, as well as single-loop designs (e.g., gooseneck, ev3, Minneapolis, MN; Welter retrieval loop, Cook, Letchworth, UK; and trefoil, EnSnare/TriSnare, Merit Medical, South Jordan, UT). All brands are modeled on the same principle: the use of a moveable Nitinol wire loop passing through a catheter. In the absence of a purpose-built loop snare, a homemade snare can be constructed with a narrow-gauge wire, such as 0.018- or 0.014-inch wire, and a selective catheter with either an end hole or a side hole, such as a Cobra catheter. Mallmann et al. [14] reported 100 % success at retrieving IFB with self-made snares; retrievals comprised 16 of 16 consecutive IFB and included partially fractured venous catheters, guide wires, a stent, and a vena cava filter, which were all removed from various locations. Snares have an excellent safety profile and are relatively atraumatic. They are simple to use and are effective for achieving a good success rate of IFB retrieval, even in inexperienced hands. The loop snare provides good perceptual feedback: operators have a good feel for the purchase they have on the ensnared device.

Proximal Grab Technique

The proximal grab technique is the basic technique in using a snare. An appropriately sized snare for the vessel is used—that is, a snare loop size equal to or slightly smaller than the vessel diameter. This is delivered via a straight guide catheter, typically either a 4F or 6F guide catheter. Once the snare is in position within the target vessel, the outer catheter is withdrawn, allowing the snare to open fully within the caliber of the vessel. The whole system is then advanced to position the open loop around (or around a selected part of) the lost IFB. The loop is closed by advancing the catheter to tightly trap the IFB, and the whole system and IFB are retrieved back to the sheath. A prerequisite for this technique to be successful is a free end on the IFB on which to grasp. If this is not the case, then there are two options: either approach from a different direction (via another puncture site), or use a shaped catheter such as a SOS Omni or a balloon that can be used alongside the snare to tilt or displace the IFB in a controlled manner to allow a free end to be present itself. The main drawback with the snare is that once the IFB is captured and the loop is closed, the IFB will want to rotate into a position perpendicular to the snare catheter (Figs. 3, 4). This is not a problem with nonrigid IFBs that can fold in half (Figs. 4, 5). However, this can be a significant problem

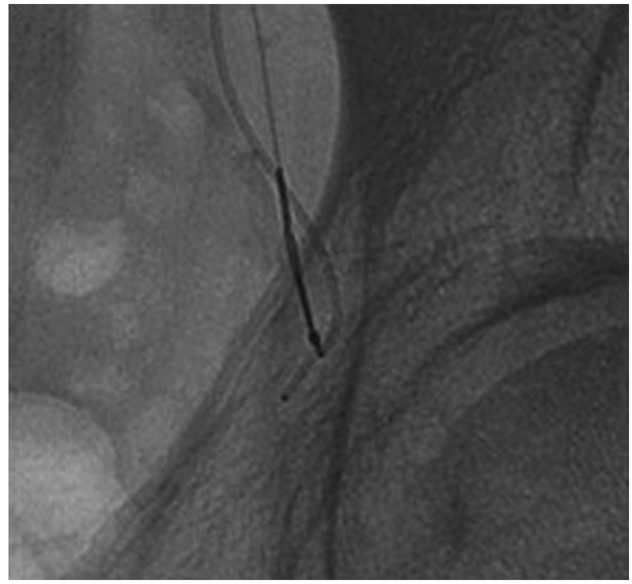

Fig. 4 A fragment of catheter sheared off in the left external iliac artery during an angioplasty procedure and was retrieved using a snare via a sheath in the right common femoral artery. The catheter is seen to be turning to an axis perpendicular to the vessel/snare catheter. However, it could still be retrieved because it was flexible. More rigid objects risk causing vessel wall damage in this situation

with rigid IFB and can prevent the negotiation of these IFB through narrow vasculature, and across vascular junctions without risk of vessel damage or perforation. To offset this, it is better to grasp the object at one end so that there is a natural trailing edge that helps keep objects aligned with the vessel axis. Even when vessels have been negotiated it may still prove impossible to retract into even a large sheath. To facilitate retrieval into a sheath, a second snare can be used from a different vascular access point to apply

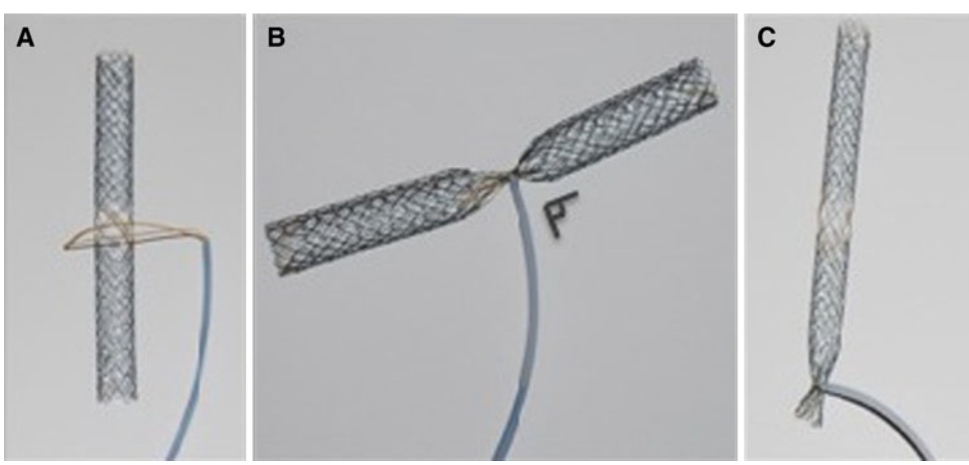

Fig. 3 Proximal grasp technique. When a snare is used to grasp an object, it tends to pull that object perpendicular to the axis of the catheter/constraining vessel (**A**, **B**). It is better to grasp the object at one end so that there is a natural trailing edge that helps keep objects aligned with the vessel axis (**C**). This is the most basic use of a snare

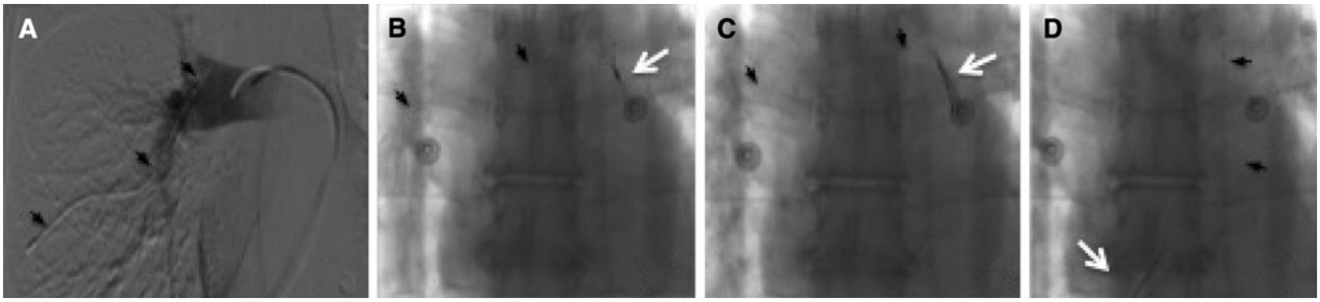

Fig. 5 The catheter segment of a Port-A-Cath detached from the subcutaneous hub and migrated into the right pulmonary artery. AnEnSnare (*white arrow*) device was used to retrieve the catheter fragment (*black arrows*) because it provided excellent flexibility tonegotiate the cardiac chambers. A Pulmonary angiogram revealing catheter fragment. B, C, D The EnSnare grasping and retrievingthe trailing catheter fragment

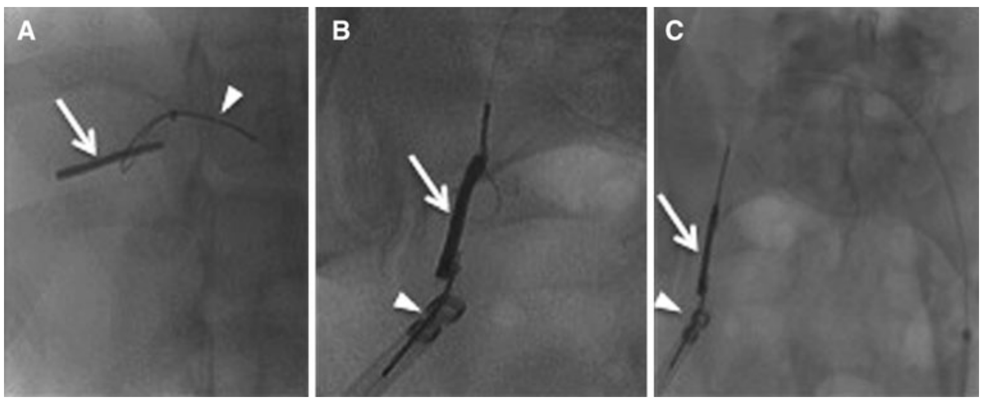

Fig. 6 In a domestic accident, a builder's nail became a high-velocity projectile and perforated the patient's skin. It was eventually located in the right hepatic vein. **A** A snare (Amplatz gooseneck snare, ev3) using the proximal grasp technique was used to capture the nail. Although it could be negotiated back to the sheath in the right femoral vein, it would not enter the sheath. **B**, **C** A second snare (EnSnare, Merit Medical) was used via the left femoral vein to snare the other end of the nail and provide counter traction, allowing the nail to be aligned with the sheath, and the nail was successfully explanted

a rotation torque to a IFB (Fig. 6). Snares can also "cheese wire" soft catheters in half if too much force is used turning one IFB into two.

Distal Wire Grab Technique

The distal wire grab approach can be attempted if a guide wire can pass through the IFB. A microsnare is used to track alongside and past the IFB, and then the snare is used to capture the distal end of the guide wire that crosses the IFB. In this manner, the IFB is constrained between the guide wire and the snare catheter. This technique is useful to keep a IFB aligned parallel to the catheter/vessel axis. A stiff guide wire is advantageous (e.g., the Amplatz super-stiff wire) (Fig. 7A, B).

Coaxial Snare Technique

The coaxial snare technique uses a guide wire and a snare to reduce the angulation between the foreign body, the snare, and the sheath. This technique is only possible with tubular foreign bodies. The goal is to pass a guide wire through the lumen of the IFB. The snare is then positioned around the guide wire that then becomes a monorail to guide the snare loop distally. At the proximal pole of the tubular IFB, the snare loop is opened and is used to capture the IFB and the guide wire together. The guide wire is now entrapped within the snare loop, and traction can be used to provide torque and to guide the proximal pole of the IFB into the sheath (Fig. 7C). Seong et al. [15] demonstrated in seven cases that this technique could be used to reliably reposition various lost tubular IFBs such that a snare and a minimum-sized sheath could be used to retrieve lost IFBs without the need to fold the IFB.

Lateral Grasp Technique

The lateral grasp technique is a variation on the distal grasp technique. In this approach, the snare is deployed distal to the IFB and opened widely. Next, a rigid guide wire is passed around the other side of the IFB and then through the snare loop. The snare is closed and grasps the guide

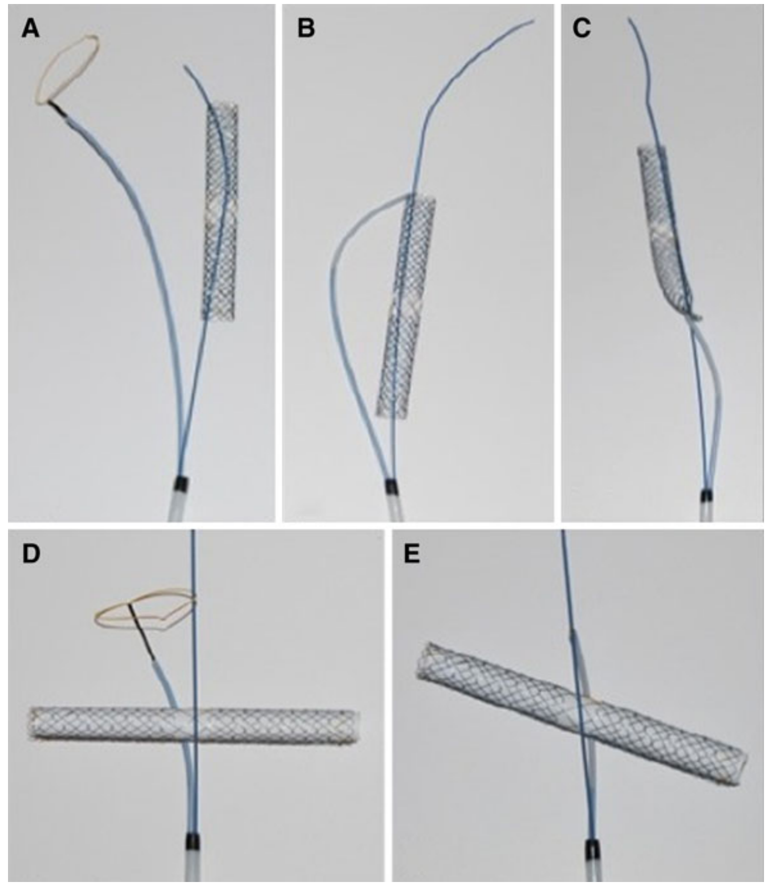

Fig. 7 **A**, **B** Distal wire grab technique. The guide wire is passed through the foreign body. The snare is passed distally alongside the foreign body and captures the guide wire distally. The foreign body is maintained in alignment with the vessel axis. **C** Coaxial grasp technique. A stiff guide wire through the foreign body helps maintain the axis of the construct along the line of the guide catheter and constraining vessel. **D**, **E** Lateral grasp technique, demonstrated with a stent. The wire and the snare pass on either side of the foreign body (i.e., the wire need not pass though the foreign body). The guide catheter is then advanced to close the construction and entrap the foreign body

wire. Both guide wire and snare catheter pinch grip the IFB between their shafts (Fig. 7D, E).

Stone Retrieval Baskets/Dormia Baskets

The Dormia basket is a well-known device that is often used in the biliary system, but it can also be used for endovascular retrievals [8, 12, 13]. It is made from two loops of Nitinol wire spirals that unfurl on deployment without significant risk of vessel wall damage. A sheath is used to open and close the basket and can easily be used by a single operator with one hand. The device provides good haptic feedback and is narrow (less than 3F), so it can be passed down a narrow guide catheter and access small-caliber vessels. It can unfurl, providing a wide loop that is advantageous to encircling the IFB. Because it is not a device dedicated to IFB retrieval, it is also relatively cheap (in contrast to the snare). In our personal experience, we found it particularly useful, especially in larger-caliber vessels. The disadvantage of baskets is that they are difficult to guide. Some makes of Dormia basket also have a rigid tip that poses a risk of endothelial wall damage.

Sheth et al. [16] reported a series of IFB retrieval with the use of Dormia baskets reporting 100 % success with percutaneously grasping the IFB, and a subsequent retrieval rate of 96 % (success in 25 of 26 procedures). They found that it was possible to remove virtually all IFBs with a Dormia basket by itself or in combination with a Sidewinder catheter, which was used to mobilize the IFB to a point where it could be captured. The IFBs included stents, embolization coils, guide wires, a pacemaker lead, and catheter fragments. Their only case of unsuccessful IFB removal was a guide wire that had been lost in a leg vein and not noticed for over a year. They reported no procedural complication after prolonged follow-up.

Small Balloon Catheter Technique

The small balloon technique is useful in the retrieval of lost stents [13, 17, 18]. This technique necessitates that a guide wire traverses through (part of) the IFB. This guide wire can then be used to guide a low-profile-design noncompliant balloon catheter within or distal to the lost IFB. It is important to select an appropriate retrieval balloon. If it is too big, the balloon will not pass through the IFB and will push the IFB further. If it is too small, the balloon will not capture the IFB once inflated.

The balloon is inflated within the stent to a low pressure only sufficient to engage the stent but not to expand it. If the balloon is deployed distal to the lost IFB, then it is gently pulled back until it engages with the IFB and the whole unit can then be gently trawled back to either the sheath or a suitable proximal landing zone. In cases of maldeployed or misdeployed stents, a balloon of suitable size can then be used to fully deploy the stent in a suitable alternative landing site. If the device cannot be retrieved into a large peripheral access sheath, then the balloon can be left inflated to secure the IFB until it can be accessed via open surgery.

It is important to avoid the guide wire passing through the struts of the stent and to have the guide wire pass directly through the stent lumen. If this occurs, it is still acceptable to use the balloon to dilate a path through the stent wall to allow distal delivery of a retrieval balloon.

The small balloon technique can also be used in conjunction with a loop snare to facilitate getting the snare loop fully around an open stent [19]. The loop snare is positioned around the proximal aspect of the angioplasty balloon that is then inflated within the presenting part of the stent. This brings the snare loop into alignment with the stent. The snare can then be advanced over the inflated balloon and stent (Fig. 8). The snare can then be used to either grip the balloon and stent together to apply traction and reposition the stent, or the balloon can be removed and snare used to crimp down the stent over the guide wire (Fig. 9). The haptic feedback with this technique is limited, but despite this limitation, this technique has a good success rate for stent retrieval of approximately 50–70 % [11, 20].

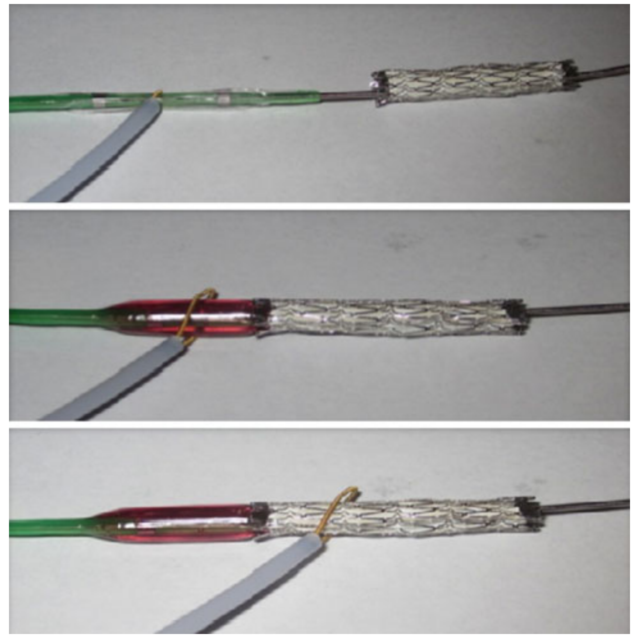

Fig. 8 Small balloon technique used in conjunction with a loop snare to capture a stent. An appropriately sized balloon is used over a guide wire through the stent. A snare can be railroaded over the balloon to the proximal end of the stent. Once in position, the balloon is inflated to bring the loop snare flush with the presenting aspect of the stent. The snare loop is then advanced to encircle the stent

Guide Wire Techniques

IFBs have been successfully retrieved without the use of a specialized retrieval device by only utilizing a guide wire [13]. In some, the guide wire succeeded where a specialized retrieval devices had failed.

Guide Wire as a Snare

As discussed previously, a guide wire can be used with a catheter to construct a homemade loop snare. Lee described a technique in which a guide wire was used to capture a lost coil from the distal middle cerebral artery. An attempt at using a 2-mm gooseneck snare had already failed and had pushed the lost coil further distally. Consequently, a microcatheter was manoeuvred distal to the coil, and a 0.010-inch microwire, the tip of which had been manually shaped into a pigtail, was introduced through the microcatheter. The microcatheter was then pulled back proximal to the coil and the microwire pulled proximally until the shaped tip came into contact with the coil. The microwire was then rotated so that the pigtail entwined with the coil, and the guide catheter was advanced to capture the coil with the guide wire tip [21].

Hairpin Trap Technique

The hairpin trap technique, described by Brilakis et al. [22], was used to capture a misplaced stent. The distal centimeters of a narrow guide wire (e.g., a 0.010- or 0.014-inch wire) is folded over to make a hairpin shape. This is inserted into a guide catheter and is passed through the stent, then pulled back and used to hook the lost stent. The distal tip of the wire is then guided back into the guiding catheter, where it is then trapped by a balloon, forming a hairpin trap. The entire system is subsequently withdrawn.

Two-wire Technique

With the two-wire technique, one guide wire is passed through the stent lumen and another, stiffer wire was passed into the stent with the expectation that the stiff wire would pass through the stent struts and not through its lumen. Once this second wire transfixes the stent, both wires are held together by a torque device and then rotated around each other multiple times until the rotation of the entwined wires is seen to reach the lost stent. This

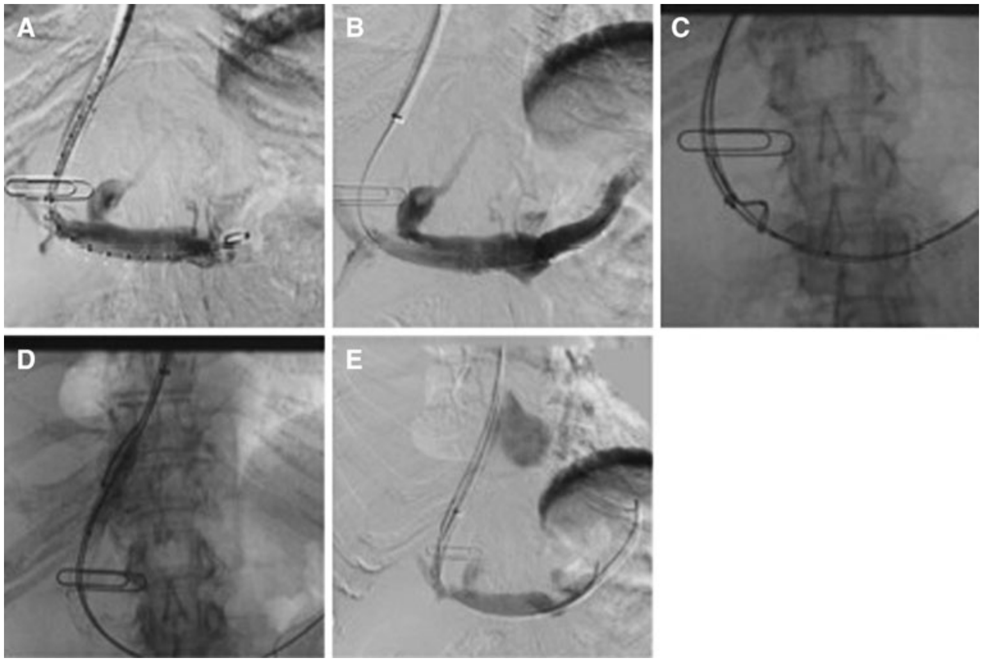

Fig. 9 The small balloon technique was used to reposition this displaced transjugular intrahepatic portosystemic shunt stent. **A** The Viatorr stent is initially deployed into satisfactory position. **B** The stent graft is inadvertently dislodged distally into the portal confluence. **C** The balloon is inflated across the proximal end of the stent, facilitating snare placement. **D** The whole system has been slowly withdrawn into the parenchymal track. **E** The balloon has been deflated and the snare removed. Venography reveals satisfactory position. Reproduced with permission from Kirby et al. [19]

intertwining of the wires produces sufficient force to capture the lost stent to allow retrieval from the coronary vessel [13]. For this technique to work, the guide wire must be of sufficient stiffness to apply a pincer-like grip around the lost stent

Intravascular Retrieval Forceps, and Biliary or Myocardial Biopsy Forceps

Dedicated intravascular forceps are now available with a variety of slightly different constructions. They have side-opening jaws and are able to pass within guiding catheters and have shapeable guide wire tips to help steer. They come in a range of sizes from 12F down to 3F. The advantage of forceps is that they do not need to have a free edge presenting, like a snare requires. The risk with forceps is causing vessel wall damage or perforation. These devices are still relatively high risk for causing iatrogenic damage and should be used judiciously; adequate training is needed for efficient and safe use. Before the development of dedicated intravascular forceps, the use of biliary, urological, or myocardial biopsy forceps was described by several authors to retrieve lost IFBs (Fig. 10) [12, 13, 23, 24]. Eggebrecht et al. [11] utilized myocardial biopsy forceps in 3 of 20 cases of lost stent retrieval and had primary success in of 2 of these cases. In the third case, a gooseneck snare had already failed to retrieve the stent, and the stent was finally retrieved via the small balloon technique. The technique for using intravascular forceps is to use multiplanar fluoroscopy to carefully position the forceps adjacent to the IFB, to then grasp the IFB and retract the system en bloc [25]. Resistance should raise concerns about the inadvertent entrapment of vessel wall, and forced repositioning should not then be attempted.

Discussion

The low incidence of IFBs means that there is a paucity of robust data in the literature. In most case series, IFB explantation is associated with 100 % survival [26]. In untreated cases, the incidence of death or serious complication is reported to range 60 % to 71 % [26, 27]. Complications include thrombophlebitis, sepsis, arrhythmia, myocardial injury, bacterial endocarditis, vessel occlusion, ischemia, and cardiac perforation.

Undoubtedly, primary prevention of IFB is the ideal. Approaches to this end should encompass adequate training of staff manipulating percutaneous part-intravascular devices, because inappropriate device handling is often the root cause of subsequent device failure and embolization. Some of the devices or techniques cited above are infrequently used (e.g., endovascular forceps), and thus adequate training is a key aspect in preventing further

Fig. 10 Angiographic images revealing occlusion in the popliteal artery (*arrow*) due to an embolized Angio-Seal foot plate. Fluoroscopic images reveal the deployment of alligator forceps (*inset*) used to retrieve the embolized material. Reproduced with permission from Boersma et al. [25]

complications that may result from the inappropriate or unskilled utilization of unfamiliar devices.

If preventative strategies fail, the best management is usually to obtain timely and urgent retrieval of a lost IFB. Clearly the risks and benefits should be judiciously balanced, and our view is that multidisciplinary team/peer discussion is advisable in all cases. It is important to remember that it may not always appropriate or possible to retrieve a lost IFB by the endovascular approach. Open surgical retrieval may be required in approximately 6–10 % of cases [10, 20, 28].

Once the decision has been made to attempt retrieval via an endovascular approach, it is essential to adequately plan the procedure. Percutaneous access sites should be carefully considered, and access sheaths should be of sufficient size. In the case of lost stents, frequently it is easier, safer, and quicker to identify a suitable vascular bed within which the lost stent can be safely and permanently parked. This strategy can help minimize patient trauma and radiation dose. The construction of the IFB is important to consider. Palmaz stents can be crimped down again with a snare, but this is arduous; repositioning the stent is simpler. Nitinol stents will be refractory to crimping down or to overexpansion because of Nitinol's thermal memory properties. With Nitinol stents, the deployment of a second rigid stent within the first can allow overdilation of the Nitinol stent and facilitate its repositioning. Once retrieved, the specimen should be sent for bacteriological evaluation.

Conclusion

The rise in the frequency of endovascular therapies has meant that complications, including IFBs, have increased. Interventionalists need to have a range of techniques, equipment, and tricks available to facilitate the retrieval of these items. The endovascular approach has repeatedly been demonstrated to have a high success rate with a low associated morbidity, and it avoids complications related to open surgical approaches.

Conflict of interest The authors declare that they have no conflict of interest.

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