"Azygous Vein Coil Implantation in Left Ventricular Assist Device Patients: Hands-on Approach"

**Short Title:** Azygous Vein coil Implantation in LVAD patients.

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**Abstract**

**Background:** Recently there have been reports of LVAD patients presenting with multiple ineffective ICD shocks. In such patients, azygous vein coil placement by providing an alternative anterior-posterior trajectory of the electrical shock vector can enable successful defibrillation.

**Objective:** This review provides a hands-on approach to azygous vein coil implantation. Additionally, we compare our tools and technique to those that have been previously described by other operators.

**Methods:** From 2018 to 2021, 8 patients were identified who underwent azygous vein coil implantation at MedStar Washington hospital center using specific tools and technique. Demographic and procedural data were obtained by retrospective review of patient charts, procedure logs, fluoroscopy and venography performed during coil implantation.

**Results:** The indication for azygous vein coil implantation was ineffective ICD shocks in 7 patients. The presenting rhythm was VF in 6/8 (75%) cases and sustained VT in 2/8 (25%) cases. Using the approach described, we were able to successfully implant an azygous vein coil in all 8 (100%) patients. There were no procedure-related complications. Post implantation, defibrillation testing (DFT) was successfully performed in 6/8 (75%) patients. One patient failed DFT testing despite the placement of an azygous vein coil. In another patient, DFT testing was not performed because the patient was in atrial fibrillation and was not systemically anticoagulated.

**Conclusion:** Placement of an azygous vein coil in LVAD patients with failed ICD shocks using the tools and technique described in this review is safe and highly efficacious (successful in 100% cases).

**Keywords:** LVAD, Azygous Vein, Ventricular Tachycardia, ICD

## Introduction

Elevated defibrillation thresholds (DFTs) or ineffective shocks is a rarely encountered scenario in the contemporary era of primary prevention ICD implantation, owing to the effectiveness of modern devices.[1] However, recently there have been many reports of LVAD patients presenting with multiple ineffective ICD shocks.[2] Methods to lower DFTs in such patients include optimizing their hemodynamics, correcting any underlying electrolyte abnormalities, eliminating any membrane active drugs (e.g., Amiodarone) that could potentially raise DFTs, and implanting additional ICD leads to provide an alternative electrical shock vector. Potential targets for the latter include the superior vena cava (SVC), subclavian vein, the coronary sinus, and the azygous vein.

Implanting a defibrillation coil in the azygous vein to lower DFTs was first described by Cesario et al in 2004.[3] Recently, this strategy was shown to allow effective defibrillation in LVAD patients with previously failed ICD shocks.[2] One can only expect that the need for such interventions will continue to rise with the increasing prevalence of patients with LVADs.[4] The purpose of this report is to provide a hands-on approach to azygous vein coil implantation using our safe and highly efficacious technique. Additionally, we highlight the advantages of using our technique, compared to those described by other operators in the past.

## Methods

From 2018 to 2021, 8 patients were identified in whom azygous vein coil implantation was attempted at MedStar Washington hospital center using specific tools and technique. Per institutional guidelines, all patients provided written informed consent for the implant procedure and subsequent defibrillation testing. Institutional review board

approval was obtained to use anonymized medical information for this report. Patients' electronic medical records including clinical notes, procedure notes, fluoroscopy and venography performed during coil implantation were reviewed.

**Azygous vein coil implantation Technique: Hands-on Approach.** (Video 1)

- Prior to the actual azygous vein coil implantation procedure, process optimization[5] was performed including preprocedural hydration, and elevation of the patient's legs to increase the central venous pressure.
- The axillary vein was accessed with a 21-gauge echo enhanced micro puncture needle by sticking while the contrast was flowing through the target vein (10–20 ml of full-strength contrast, followed by 30–50 ml of flush with normal saline).
- A stiffened micro-puncture dilator and 5-F catheter was advance over the .018-in wire. The stiffened dilator was removed, and a 0.035-in glide wire was introduced through the 5-F catheter, into the subclavian vein.
- A height adjustable table was placed perpendicular to the patient. The table orientation allows long wires, catheters, and sheaths to remain in their natural orientation as they exit the body. Hence minimizing the risk of them falling off the table and eliminating unnecessary bends and curves.
- A standard vein selector (braided catheter with 5-F outer diameter (OD), 75 cm long catheter with a soft tapered tip) was advanced over the 0.035-in glide wire to the SVC/RA junction.
- The glide wire was removed, and a contrast injection system consisting of a 30 ml contrast reservoir syringe, a 10–12 ml control syringe, a 3-way stopcock, a 12–18 in

tubing with male and female ends, and a Y adapter with hemostatic valve and rotating hub, was assembled and connected to the standard vein selector.

- The fluoroscopy camera was positioned in the left anterior oblique (LAO) 30 degrees angulation.
- The azygous vein starts at the level of the first and second lumbar vertebrae and arises from the union of lumbar veins and the right subcostal vein. It courses along the right vertebral column and arches posteriorly over the right main bronchus to empty into the SVC. (Figure 1) Hence, we started searching for the azygous vein at the beginning of superior vena cava using puffs of contrast rather than the “poke and pray” wire technique.
- The azygous vein was located using gentle contrast injections through the standard vein selector. When possible, cannulating the azygous vein with a vein selector was preferred, as they are much softer and easier to advance into the azygous vein than the JL 3.5 diagnostic catheter. (Figure 2A)
- If we had difficulty locating the azygous vein using the standard vein selector, we switched to a Judkin’s left (JL) 3.5 diagnostic catheter attached to the contrast injection system. Since the azygous vein is a posterior structure, we applied counterclockwise torque to the JL 3.5 diagnostic catheter to locate it.
- After engaging the azygous vein, a 0.035-in glide wire was advanced as far as possible. (Figure 2B)
- The standard vein selector or the JL 3.5 diagnostic catheter was advanced deep into azygous vein over the glide wire. (Figure 2C and Figure 2D)
- The glide wire was then exchanged with a 0.035-in Amplatz extra stiff wire. Ideally the Amplatz extra stiff wire was deposited below the level of the diaphragm.

- The Worley sheath (9-F inner diameter peel-away platform) along with its hand shaped/curved stylet was advanced over the Amplatz wire, till the tip of the stylet was at the origin of the azygous vein. The pre curved Worley sheath reduced kinking as the sheath negotiated the curves at the brachiocephalic vein – SVC – azygous vein intersection. (Figure 2F)
- The Worley sheath was advanced over the Amplatz extra stiff wire deep into the azygous vein. (Figure 2H)
- The coil with the stylet in place was advanced through the Worley sheath adjacent to the Amplatz wire and placed deep in the azygous vein posterior to the heart. (Figure 2I)
- The Amplatz wire was then removed.
- The Worley sheath was then peeled away maintaining stable position of the coil. (Figure 2J)
- The Stylet of the azygous coil was then removed. (Figure 2K)
- Defibrillation testing was then performed.

**Results**

The mean age of our study participants was 51 years, and majority were men 6 (75%). All study participants suffered from severe left ventricular systolic dysfunction and had an LVAD in place. Additionally, 7 patients had preexisting ICDs, which were placed prior to their LVAD implantation surgery. Six (75%) patients had history of successful ICD shocks prior to LVAD implantation surgery. The indication for azygous vein coil implantation in all cases was failed defibrillation. The presenting rhythm in 6 (75%) of cases was VF, and sustained VT in 2/8 (25%) cases. Supported by their LVADs, all patients were awake at the

time of VT/VF and majority 5 (62%) experienced greater than four consecutive ineffective ICD shocks prior to their presentation. (Table 1)

In all 8 patients an azygous vein coil was successfully implanted using process optimization plus the tools and technique described. (Table 2) There were no complications related to azygous vein coil implantation procedure. Additionally, no changes in the parameters of other non-targeted leads, including sensing, capture threshold, and impedance was noted.

Defibrillation testing was performed in 7 patients. One patient was noted to be in atrial fibrillation and was not receiving therapeutic anticoagulation at the time of the implant procedure, hence DFT was not performed. In one patient DFT was not successful, despite the azygous vein coil and using the highest energy generator available at the time (Biotronik 45 J). In this patient we additionally placed a subcutaneous coil from the left subclavian vein to the RV. VF was again induced and the patient was unsuccessfully shocked from the azygous vein coil to the intravascular placed subcutaneous coil. Due to the lack of other options for this patient, the patient was referred for urgent cardiac transplantation workup.

**Discussion**

Most patients with severe stage D systolic heart failure necessitating LVAD therapy have ICDs implanted prior to their LVAD surgery. Although, ICD therapy has not been conclusively shown to provide mortality benefit in LVAD patients[6,7], owing to the high incidence of ventricular arrythmias[8,9], therapies including shocks are programmed in most patients. Recently an increasing number of LVAD patients have been reported to present with multiple ineffective ICD shocks.[2] The high DFT's in LVAD patients may be secondary to

the severity of LV dysfunction or a post LVAD rise in defibrillation thresholds.[10,11] Post LVAD rise in DFTs may be due to changes in cardiac geometry and shunting of the electrical shock due to vector shifts caused by the introduction of intrathoracic metal.[10] Unfortunately, most patients with LVADs are fully conscious while being shocked by their ICD repeatedly as their hemodynamics are supported by the LVAD. The latter can lead to major psychological trauma to the patient.

Frequently used but often ineffective options for LVAD patients with appropriate but failed ICD shocks include: 1. Programming changes including altering vector polarity, adjusting tilt and pulse width of the biphasic shock[12] 2. Repositioning of the right ventricular ICD lead, 3. Upgrade to a dual coil ICD system, 4. use of a higher energy generator, 5. The addition of a second defibrillator coil in a different location e.g., in the subclavian vein or the coronary sinus, and 6. Implantation of subcutaneous ICD. Although there have been case reports of implantation of subcutaneous ICD in patients with an LVAD, these devices are not considered optimal for such patients.[13,14] Some potential issues include proximity of the ICD pocket site to that of the LVAD, electromagnetic interference from the LVAD, and inability to deliver anti-tachycardia pacing (ATP). By comparison, azygous vein coil placement, by providing an alternative anterior-posterior trajectory of the electrical shock vector, can be very effective in lowering DFTs.

In our series, the RV ICD lead position and parameters including shock impedance were within normal limits for all patients, hence repositioning the RV lead would likely be of minimal benefit. Four patients previously had a well-positioned superior vena cava coil (dual coil RV lead). Additionally, 3 patients previously had biventricular ICDs. Even though LV pacing is often turned off in patients with LVADs, the presence of a pacing lead in the CS

makes addition of an ICD lead in the CS more challenging. Therefore, our approach was to implant an azygous vein coil to provide an anterior posterior shock vector. We were able to successfully place the azygous vein coil in all 8 (100%) patients. Additionally, we placed the high energy generator in 4 (50%) of the patients.

The largest case series of azygous vein coil implantation (10 patients) was published by Cooper et[15] al in 2009. In their series, they noted a greater than 90 % success rate of azygous vein coil implantation using their tools and technique. Their failure to implant the coil was secondary to their inability to advance the long sheath around the curve into the azygous vein. In another series, Seow et al[16] published a series of 3 patients and noted a success rate of 66%. In comparison, we were able to implant the azygous vein in all (100%) LVAD patients using our tools and techniques, in whom it was attempted. Additionally, our technique has some cardinal differences than those previously described.

- We emphasize the importance of pre procedure process optimization including pre-hydration, height adjustable perpendicular table position etc.[5]
- When implanting from the left side, a JL-3.5 catheter is better suited to engage the azygous vein when compared to the JR-4 catheter as described by others.[15,16] The secondary and tertiary curves direct the JL-3.5 catheter inferiorly and the primary curve engages the azygous vein with counterclockwise torque. (Figure 3)
- We recommend using the AL-1 catheter to engage the azygous vein when implanting from the right side. (Video 2)
- Cooper et al[15], described using the right mainstem bronchus in the anterior posterior fluoroscopy view as a reference starting point for locating the azygous vein. In contrast, we encourage positioning the catheter in the SVC, central to the origin of

the left brachiocephalic vein and then using gentle pullback and counterclockwise torque to point the catheter tip towards the left side of the patient while imaging in LAO 30 degrees.

- We strongly encourage using gentle contrast injections through specifically shaped catheters to visualize the origin of the azygous vein rather than probing with a wire to locate the azygous vein. “Poke and pray” with a wire compared to contrast guided catheter engagement, adds time to the procedure and makes it more challenging to locate the azygous vein.
- Once the azygous vein is engaged and a catheter (standard vein selector, JL-3.5 or AL-1) is advanced to the level of the diaphragm over the glide wire, we recommend routinely exchanging the glide wire with an Amplatz wire, and then advancing the long pre curved sheath with a hand curved dilator over the Amplatz wire to prevent kinking of the sheath at the SVC – azygous vein junction.
- In contrast to previous reports, we recommend advancing the ICD coil adjacent to the retained Amplatz wire, which keeps the long sheath from kinking.

**Conclusion**

The prevalence of LVAD patients is expected to continue to rise in the coming decades. Azygous vein coil implantation is probably the most effective bail out strategy for such patients who present with ineffective ICD shocks. Azygous vein coil placement can be accomplished safely and with a high success rate when a standardized meticulous implantation technique such as the one described in this review is followed.

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|---|---|
| **Age, years** | 51 ± 11 |
| **Female** | 2 (25) |
| **Hypertension** | 8 (100) |
| **Diabetes** | 3 (38) |
| **Dyslipidemia** | 4 (50) |
| **Smoker** | 4 (57) |
| **Etiology of cardiomyopathy** | |
| Ischemic cardiomyopathy | 1 (12) |
| Non-ischemic cardiomyopathy | 7 (88) |
| **LVAD type** | |
| HeartMate III | 4 (50) |
| HeartMate II | 1 (12) |
| HeartWare | 3 (38) |
| **Type of ICD** | |
| None | 1 (12) |
| Single Coil | 3 (38) |
| Dual Coil | 4 (50) |
| **Indication for ICD implantation** | |
| Primary prevention | 7 (88) |
| Secondary prevention | 1 (12) |
| **History of successful ICD shocks pre-LVAD** | 6 (75) |
| **Presenting arrhythmia** | |
| Ventricular Fibrillation | 6 (75) |
| Sustained Ventricular Tachycardia | 2 (25) |
| **Number of Ineffective ICD shocks at presentation** | |
| 0 – 3 | 3 (38) |
| 3 – 6 | 5 (62) |

Table 1. Baseline characteristics and clinical presentation.

277 Values are mean ± SD or n (%).

278 ICD = implantable cardioverter-defibrillator; LVAD = left ventricular assist device.

279

| Patient | Subclavian Fibroplasty Performed | Side of Implant | Catheter Used | Lead Implanted | Success of DFT | Energy at which DFT was performed |
|---|---|---|---|---|---|---|
| 1. | Yes | Right | AL-1 | Medtronic SQ coil 6996SQ-58 | Successful | 30 J |
| 2. | Yes | Left | Std vein selector | Medtronic 6937A-58 | Successful | 45 J |
| 3. | No | Left | Std vein selector | Medtronic 6937A-58 | Failed | 45 J |
| 4. | No | Left | JL-3.5 | Medtronic 6937A-58 | Not performed | |
| 5. | No | Left | JL-3.5 | Medtronic 6937A-58 | Successful | 30 J |
| 6. | No | Left | JL-3.5 | Medtronic 6937A-58 | Successful | 30 J |
| 7. | No | Left | JL-3.5 | Medtronic 6937A-58 | Successful | 45 J |
| 8. | Yes | Left | JL-3.5 | Medtronic 6937A-58 | Successful | 45 J |

Table 2. Procedural interventions and outcomes.

VF = Ventricular Fibrillation; VT = Ventricular Tachycardia; AL-1 = Amplatz left 1 diagnostic catheter, JL-3.5 = Judkins Left 3.5 diagnostic catheter; Std = Standard; DFT = Defibrillation Threshold testing.

Figure 1. Anatomy of the Azygous vein. The black line shows a Judkins left 3.5 catheter as it engages the Azygous vein.

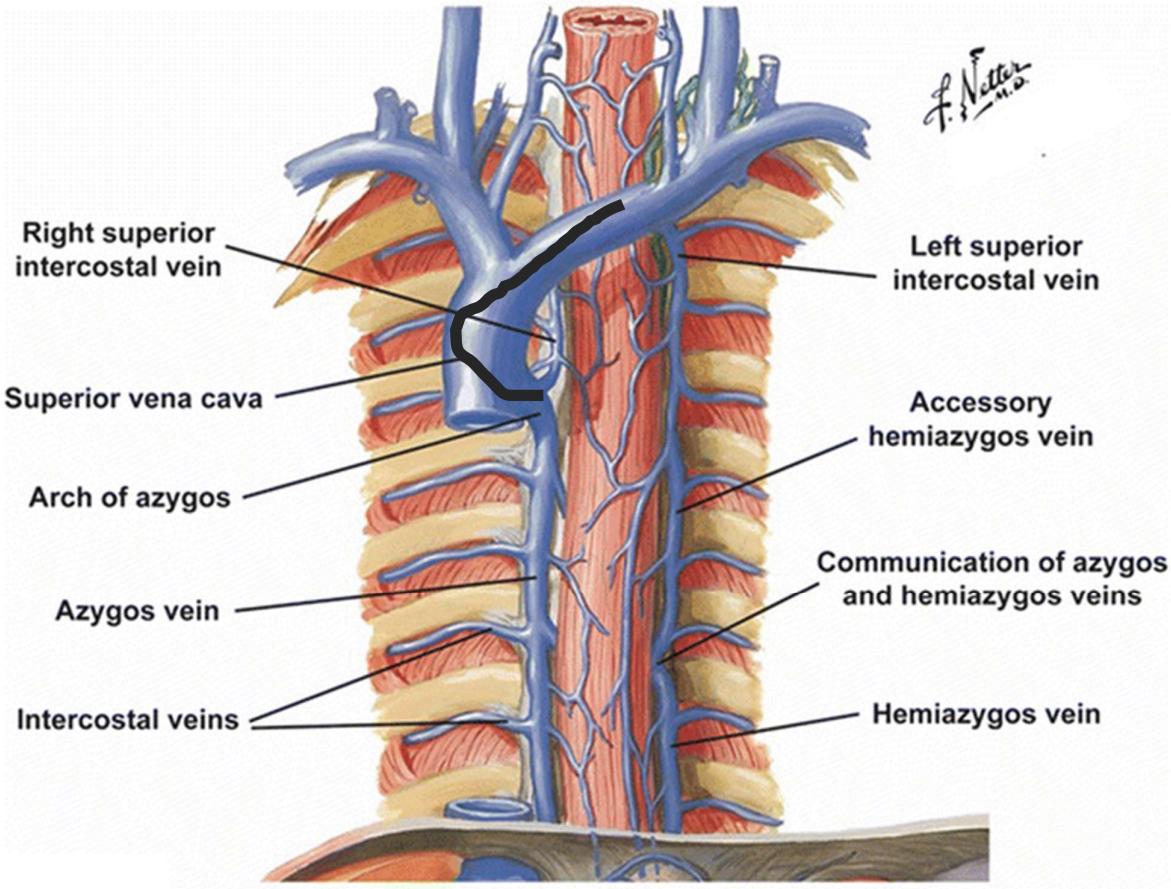


Figure 2. Azygous vein Coil implantation Technique. Left sided technique ‘A-K’, Right sided technique ‘L’.

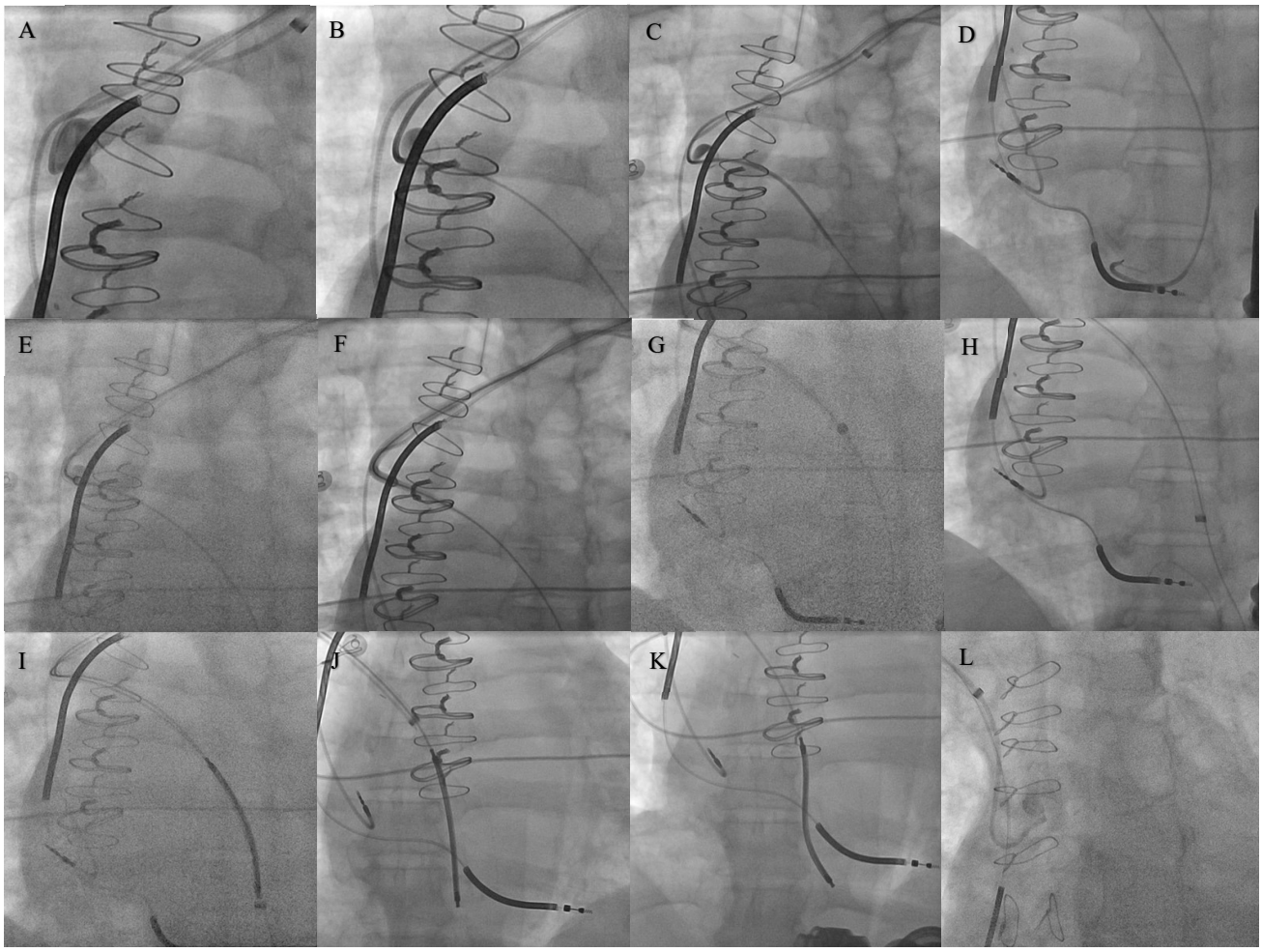
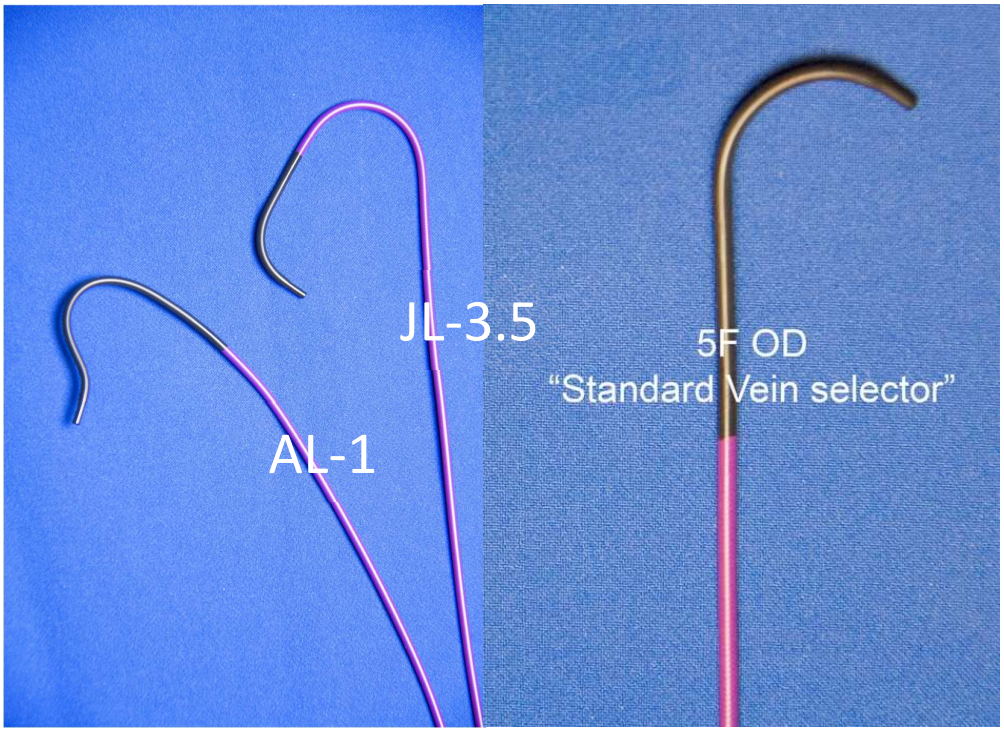


Figure 3. Catheters used for engaging the Azygous vein.

AL-1 = Amplatz left 1 diagnostic catheter; JL-3.5 = Judkins Left 3.5 diagnostic catheter; Standard vein selector.



Videos:

Video 1: Azygous vein coil implantation technique from the left side.

Video 2: Azygous vein coil implantation technique from the right side.