INNOVATIVE TECHNIQUES

A Review of Innovative Strategies for CRT Implantation: Part I

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ABSTRACT. The response to cardiac resynchronization therapy using transvenous epicardial leads may be limited by difficulty in introducing the left ventricular lead in an optimal location due to anatomic obstacles. This article describes advanced techniques to facilitate implants in patients with difficult anatomy. Subclavian venoplasty can be used to allow access to the coronary sinus in patients with subclavian vein stenosis. Venoplasty techniques for dilating valves and strictures within the coronary sinus and its branches are described. The use of retaining guidewires for stabilizing the guide catheter is also illustrated.

KEYWORDS. cardiac resynchronization therapy, coronary venoplasty, coronary venous stenting, left ventricle, lead delivery techniques.

Introduction

Cardiac resynchronization therapy (CRT) is a well-recognized and highly effective treatment strategy for heart failure, but it does have limitations. These include a 70% response rate, occasional implant failures, and frequent inability to position leads in an optimal location using the conventional transvenous route. Newer implant approaches include percutaneous epicardial lead implant or left ventricular (LV) endocardial pacing via a transseptally placed LV lead. However, these approaches have significant shortcomings that have prevented their adoption into clinical practice. LV lead delivery via the coronary sinus (CS) remains the methodology of choice at the present time.

This article focuses on innovative techniques for implanting transvenous LV leads in patients with difficult anatomy or in targeted locations. Many are based on coronary and peripheral arterial interventional tools and include the use of balloons for venoplasty as well as the introduction of stents in the coronary veins.

Subclavian venoplasty

Stenosis or total occlusion of the subclavian vein (Figure 1) usually occurs as a result of previously implanted pacemaker/implantable cardioverter-defibrillator (ICD) leads or surgery. With proper technique, these stenotic veins can be safely dilated or stented in the large majority of cases, thereby avoiding an implant on the contralateral side or thoracotomy for an epicardial implant. Success is defined as passage of the transvenous lead through the obstruction to its final location. The literature suggests that other causes of subclavian vein stenosis, e.g. thoracic outlet syndrome, do not respond as well to interventional techniques. However, in these publications, success is defined as long-term patency of the subclavian vein, which is not a requirement for transvenous lead implant.

Incomplete obstruction

If the obstruction is not complete, it is first crossed with a guidewire. We prefer a 0.035 hydrophilic-coated wire. Once it is confirmed that the guidewire is indeed within the lumen of the superior vena cava (SVC) (and not in a side branch, or the azygos vein), a peripheral interventional balloon catheter is advanced over the wire.

The balloon catheter is sized according to the size of the subclavian vein. A 6–8F balloon catheter will suffice for most cases. Balloon inflations are then performed for 1–2 min. The balloon is removed while keeping the guidewire in place. A venogram is then performed. Success is defined as the ability to pass the 8F sheath
through the stenotic portion of the subclavian vein and to position the lead in its target area.

On occasion, the stenosis in the subclavian vein is so severe that it will not admit a 6F balloon. In this circumstance, a smaller balloon is passed across the lesion to predilate it before the bigger balloon can be employed.

**Complete obstruction**

When there is a complete obstruction of the subclavian vein due to previously placed leads that are no longer in use, it is possible to extract the inoperative lead, usually with laser assistance. A 0.035 guidewire is passed through the lumen thus created, and venoplasty is performed to dilate the stenosis sufficiently to allow passage of a sheath and new lead.

**Obstruction involving the superior vena cava**

When the stenosis involves the junction of the subclavian and the SVC, there is a small possibility of a tear in the SVC, which can lead to rapid hemodynamic collapse. When the obstruction involves the SVC, we prefer that a second operator pass a guidewire retrograde from the femoral vein, through the SVC, and across the subclavian lesion (Figure 2). In the case of a serious SVC tear, a peripheral stent can be rapidly deployed from the femoral vein to seal off the tear.

Our success rate with subclavian venoplasty alone is about 70%. If the post-venoplasty angiogram shows an inadequate result or a large dissection, we have a low threshold for employing a peripheral stent in the subclavian vein. With stenting, the success rate increases to 90%.

**Coronary venoplasty**

The technique of using coronary and peripheral arterial balloons for dilating valves and strictures in the CS and its branches has been elegantly described by Worley. Various anatomical obstacles to LV lead delivery can be overcome with these interventional techniques. This is especially important in the case of unfavorable anatomy, and also when an LV lead must be delivered to a specific location as determined by preoperative testing for electrical or mechanical dyssynchrony.

**Dilatation of the Thebesian valve**

The CS ostium is guarded by a variously developed membranous valve, the Thebesian valve (Figure 3). On occasion, the valve may actually be a fenestrated membrane covering the entire CS ostium. Such valves

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**Figure 1:** Venoplasty of a severely narrowed subclavian vein encountered during upgrading of an implantable cardioverter-defibrillator to a cardiac resynchronization therapy defibrillator device. (a) Venogram of left subclavian vein, which was obtained when difficulty was encountered advancing a guidewire following subclavian puncture. There was subtotal occlusion of the vein (arrow) with little flow into the inferior vena cava. (b) A 0.035 glidewire successfully negotiated the stenosis and is seen in the superior vena cava accompanying the previously placed pacing leads. A 5F, 40-mm-long peripheral balloon is advanced over it and inflated. (c) Venogram after balloon inflation shows improved contrast flow into the inferior vena cava but significant stenosis remains, extending over 2 cm, suggesting the balloon was undersized compared with the vessel. (d) A 7F, 50-mm peripheral balloon replaces the previous smaller balloon and is inflated; note remaining area of stenosis (arrow), which vanishes as inflation is continued and pressure increased. (e) Final left ventricular lead placement through dilated subclavian vein.
serve as impediments to the introduction of the guide catheter in about 15% of cases. They can be usually negotiated by a hydrophilic-coated guidewire but do not allow the guide catheter to advance. A peripheral balloon of appropriate diameter may be passed over the guidewire and inflated to dilate the Thebesian valve. The “jump” technique, described subsequently, is preferred in such cases. We use a 0.035 glidewire to cross the valve and a short 20–30 mm peripheral angioplasty balloon for dilating the valve; the diameter of the balloon should be less than the CS, and a 4-mm balloon suffices in most cases if the “jump” technique is used.

Dilatation of an obstructive valve of Vieussens

The valve of Vieussens is usually a variously developed bi- or trileaflet valve, but not always; it is positioned at the junction of the CS and the great cardiac vein (Figure 3b). When positioned proximally, it can impede the introduction of the catheter, and distally located valves may impede the passage of the LV lead. It can usually be negotiated by a coated 0.014 guidewire and dilated with an appropriately sized (same caliber as CS), non-compliant balloon.

Jump technique for venoplasty

This methodology is employed when the guide catheter can be advanced right up to the obstruction, which has been crossed by a guidewire (Figure 4). It can be used for most obstructions in the main CS and in the major side branches. Figure 4a and Figure 5 show obstructive valves at the origin of large lateral branches. Once the lesion has been crossed with a stiff guidewire, a non-compliant balloon of appropriate caliber and length is...
advanced over the wire and across the lesion. Half of the balloon lies within the guide catheter, which abuts the constriction, while the distal half crosses the obstruction (Figure 4b). The caliber of the balloon is always at least 1–2 mm larger than the guide catheter. Thus, a 4-mm balloon would be used with a standard 8F guide. The balloon is then inflated; an indentation, representing the obstruction, is sometimes seen. Disappearance of the indentation indicates successful dilatation of the obstruction. When the indentation disappears, the guide is advanced while the balloon is simultaneously deflated. The guide jumps across the obstructive valve, which has been predilated by the larger balloon before it has a chance to recoil (Figure 4c). A venogram is always performed post dilatation to document that there is no dissection (Figure 4d). This method is almost always successful when executed properly.

Dilatation of valves in side branches
Large side branches of the CS have well-developed, obstructive valves at or close to their origin in many cases (Figure 5). The jump technique should always be used in these cases, provided the take-off angle of the side branch is not too acute to allow sub-selective cannulation with the guide catheter.
Dilatation of coronary sinus stenosis

Stenosis of the main CS is rarely encountered but, when present, it may impede further passage of the LV lead (Figure 6). Such stenoses may be dilated with an appropriately sized balloon. Large dissections appear more likely in such cases (two of four cases suffered dissection in our experience), but can be easily and rapidly treated with an appropriately sized peripheral stent. Venous stents will be discussed in Part II of this review.

Venoplasty of distal obstructions

Venoplasty can be employed when there are more distal obstructions in side branches, but these valves are usually relatively elastic, web-like structures and tend to spring back after inflation of the balloon. Our success rate with venoplasty in distal obstructions is about 50%, whereas it is >90% when the jump technique is used for proximal obstructions and locations where the guide catheter can be positioned abutting the lesion. Coronary stents may be employed when peripheral venoplasty fails.

Cutting wire balloon

The success of plain venoplasty can be augmented by introducing a stiff “buddy wire” alongside the balloon before inflation. In theory, this wire “cuts” rather than merely stretches the obstructive valve and may augment the success of the venoplasty.

Implant tips for successful coronary venoplasty

- Always attempt to visualize the distal vessel with a contrast injection before attempting venoplasty to assure that balloon inflation occurs in the main branch and not in a tiny side branch, which the guidewire may have unwittingly cannulated.
- Confirm the results with a “proof shot”; if a serious dissection is seen, the guidewire should always be retained, the balloon removed, and an appropriately sized coronary or peripheral stent deployed.
- Use a non-compliant balloon and a stiff guidewire, preferably one with a hydrophilic coating. Non-compliant balloons are more successful in dilating venous valves and obstructive strands but, conversely, are more difficult to advance across bends in veins. This problem is compounded when long, non-compliant balloons are employed. Predilatation with a shorter, compliant balloon or a maximally stiff guidewire may be required.
- If a guidewire has negotiated a particular side branch, another guidewire will tend to track alongside it into the same branch. This is called a “buddy wire” in interventional parlance, as the new wire tracks along with its “buddy”.
- If a 5F or smaller lead is used, a coronary balloon up to 5F in size can be passed through the same 8F guide catheter without removing the lead. (Larger leads or larger peripheral balloons require that the balloon be passed through a separate guide catheter.) The wire over which the lead is passing should be retained across the obstruction, a separate guidewire passed across the obstruction “buddy fashion”, and the balloon advanced across the new guidewire to cover the stricture. The lead guidewire will then act as a “cutting wire”.
- Following several long (1-min) inflations, the balloon is removed (the guidewire is retained in case a stent is needed) and a venogram obtained. If no dissection is seen, the lead is advanced across the stricture.
- In patients with previous thoracotomy or myocardial revascularization, there is little chance of a dissection leading to tamponade, as the pericardium is adherent to the myocardium. Dissections in such cases are treated conservatively and not stented.

Using guidewires for support

Support guidewires can be used in several ways. The presence of a guidewire in a different, usually more distal branch while a small caliber (5F or less) lead is advanced can help prevent the guide catheter from backing out of the CS when the lead is advanced. It is particularly useful when the guide catheter cannot be advanced distally into the CS because of a prominent valve of Vieussens.

This technique is especially useful for positioning a lead in the middle cardiac vein (MCV). The latter is a very constant branch, which usually arises from the most proximal part of the CS, but may sometimes arise from the right atrial floor just proximal to the CS ostium. It courses along the posterior interventricular sulcus, and in itself is not an inviting target for lead placement unless electrical or mechanical delay is documented along the
inferior wall. It frequently gives rise to communicating branches of variable size that course over the lateral wall of the left ventricle, and these, when large, may form attractive targets for lead placement in the absence of other targets (Figure 7).

Cannulation of this vein is hindered by its proximal location and acute angle of origin from the CS. Withdrawing the guide catheter too far, even with a sub-selecting inner catheter in place, may lead to loss of cannulation. This can be prevented by using a support guidewire introduced into a distal branch of the CS, usually the anterior branch (Figure 8a). The guide catheter is gradually withdrawn until it comes to lie slightly proximal to the origin of the MCV. A contrast injection is performed to delineate its origin, and a static image saved as a road map showing the way into the MCV (Figure 8b). The support guidewire prevents decannulation as the guide catheter is withdrawn. Even if the guide is retracted into the right atrium, the support wire forms a rail over which the guide can be repositioned in the CS.

Using the roadmap, another 0.014 guidewire is directed deep into the MCV. The support guidewire is removed. The guide catheter is then passed selectively into the MCV over the guidewire, and a lead is delivered in the usual way (Figure 8c).

Conclusion

The techniques of venoplasty and support guidewires significantly increase the chances of delivering an LV lead into a particular side branch of the CS, and reduce the time required for lead placement, provided essential equipment and trained personnel are immediately available in the electrophysiology laboratory. The role

Figure 7: Positioning a left ventricular (LV) lead over the lateral wall via the middle cardiac vein (MCV) in a patient who received two LV leads located in specific coronary sinus (CS) branch locations as part of a research protocol. (a) An LV lead has been positioned in the middle of a high lateral CS branch; the guide catheter has been retained. A venogram through a second guide catheter selectively engaged in the MCV demonstrates a small communicating branch coursing over the lateral wall (arrow), which was targeted for the second lead. A mid-septal right ventricular lead and a high septal femoral decapolar mapping catheter are also seen. (b) A second LV lead has been positioned in the communicating branch after dilatation with a 2.0 × 15 mm balloon to allow it to accommodate the LV lead. Venogram is performed to confirm absence of dissection and confirm lead location (solid arrow). A positive fixation LV lead is seen in the high lateral branch (barred arrow).

Figure 8: Support guidewire technique for cannulating the middle cardiac vein. (a) Following cannulation, a support guidewire has been advanced into the anterior branch of the coronary sinus (CS). Arrows outline the course of this wire. The guide has been withdrawn to the level of the CS ostium. A second guidewire has been directed into the middle cardiac vein (MCV). A right ventricular apical lead is also seen. (b) Venogram shows the support guidewire has been removed, and the guide directed into the MCV (white arrow) over the guidewire (black arrow marks tip of guidewire). Arrows delineate course of communicating branches of MCV. (c) A left ventricular lead positioned in communicating branch of MCV. Note that the lead could not be advanced as far over the lateral wall as in Figure 7, since venoplasty to dilate the communicating branch was not performed.
of venous stents for targeted lead placement and for sealing off coronary venous dissections will be discussed in Part II of this review.

References


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