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Advanced Techniques for CRT Implantations

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1. Introduction

Cardiac resynchronization therapy (CRT) is an important breakthrough for the drug-refractory heart failure patients with reduced left ventrical ejection fraction (LVEF: <35%) and wide QRS (>120 ms). The primary objecive of CRT is the coordination of the myocardial contraction with a right atrial (RA), right ventrical (RV) and a left ventrical (LV) lead and a biventricular device. The standard approach for implantation of the LV lead is transvenous epicardial approach through the subclavian vein to the lateral or posterolateral sidebranch of the coronary sinus. The average implantation time of CRT in high volume centers is under 120 minutes. Nowadays the procedural success ranges between 87% and 96% (Alonso, 2009). Early complications were seen in 10% and late complications were reported in further 5.5% (Khan et al., 2009). However we do not have all the evidence based predicting criterias to select the CRT responders and the different definitions of responders are numerous (Paul et al., 2009), the basics of all comparison is the successful left and right ventricular lead implantation. The growing numbers of heart failure patients recieving CRT and the limitation of the first line transvenous approach enhanced the evolution of alternative techniques. In this chapter we focus on the advanced CRT techniques which might help to reach the optimal lead positions and increase the success rate of implantations.

The standard transvenous approach unfortunately has significant drawbacks as it is totally dependent on the inconsistent venous anatomy. The tributaries of the coronary sinus is usually visualised by the late phase of left coronarography, direct contrast injecion or by inserting an occlusion balloon into the coronary sinus (CS). Several reasons can cause the inabilty to reach the desired sidebrach and to insert the LV lead. The main reasons are: inability to cannulate the CS caused by dilatated right atrium, atypical orifice of CS, prominent Thebesian valve, small vessel size of the CS, severe kinking of the vein or venous valve in the CS. The secondary reasons are the high pacing threshold or phrenic nerve stimulation at the optimal site, inability to fixate the lead at the desired position and the insuffitient experience of the implanters. Stenosis or occlusion of the subclavian vein, or presence of a persistent left superior vena cava might be the cause for alternative LV implantations. Small or occluded sidebranches or tortuous branches and CS dissection or perforations might overcome with advanced transvenous techniques.

The selection of the optimal site is an unsettled debate. Several noninvasiv and invasive techniques were investigated to confirm the optimal site, but no clear proven evidence is shown for the selection. However there is a consesus that the lateral and posterolateral veins are preferable rather than the anterior or apical veins. The anterolateral vein might be selected as a last resort in the absence of lateral and posterolateral veins. The identification of the veins

and their course can be followed by multiple flouroscopic views 30-60º LAO. Finding the individual optimal site and the access to that region is the task for the implanters.
The alternative approaches may be classified in terms of access: open chest or percutaneous, the lead insertion can be transvenous or transatrial. The lead tip site can be differentiated as epicaridal or endocardial.

2. Transvenous epicardial approach – LV lead in the tributaries of coronary sinus

The first line approach for LV lead implantation is transvenous epicardial access, through the coronary sinus to the tributaries. It is less invasive, can be performed in local anaesthesia and therefore preferable. The most challenging part of the implantation is the positioning of the left ventricular electrode through the coronary sinus (CS). The standard technique is well known and widely used in CRT implanting centers. In this section we emphasize the advaced alternative techniques which might help to overcome difficulties and failure components during the standard technique.

2.1 Cannulation of the coronary sinus

The main reason for failure in CRT is the inability to canulate the CS. The first essential step is to get clear view of the coronary venogram. Preprocedural venography can be visualized at the late phase of left coronarography performed as the part of the rule out of ischaemic heart disease of the heart failure patient. The position of the orifice, the angle of the beginning of CS, tortuousity and diameter of the vein are valuable informations for the selection of target vessel and the implantation approach. With the known unique limitation of the vascular venous anatomy and the reachability of the desired optimal site, the selection of the CRT techniqe is the implanters responsibility.
Additional help can be to position and fixate the RV lead into final place at the beginning of the procedure. The movement of the lead might show the tricuspid valve as a landmark. After fixation and threshold test RV lead ensures the further procedure by the ability to pace the ventricle.
Beacuse of interindividual differences of the geometry of the right atrium and CS variatons, several fixed shaped and deflectable sheaths are used to cannulate the orifice. (Fig. 1.)

2.2 Atypical orifice of CS, prominent Thebesian valve, small vessel size of the CS

In cases of unsuccessful cannulation of CS with the fix or flexible catheters, coronary angiography catheter can be inserted into the guiding catheter to create individual curves. Regularly Amplatz II curved catheters advanced 1-5 cm distally of the tip of the guiding catheter give help to manipulate with a new curve. By changing the length of advancement and small rotations of the angiographic catheter in the guiding catheter a great variety of shaped curves can be created. Depending on the atrial anatomy Amplatz I or III, Judkins Right or Multi-Purpose angiography catheter might find the orifice more easily. Contrast is injected through the catheters to identify the orifice. After cannulation, inserting a guidewire through the catheter helps to advance the catheter deep into the coronary sinus safely. The CS sheath is then forwarded over the coronary catheter. Contrast injection through the guide catheter shows the coronary sinus venogram. In some cases occlusion balloon inflated in the main branch and injection of contrast into the other lumen can prove smaller distal sidebranches (Fig.2.).

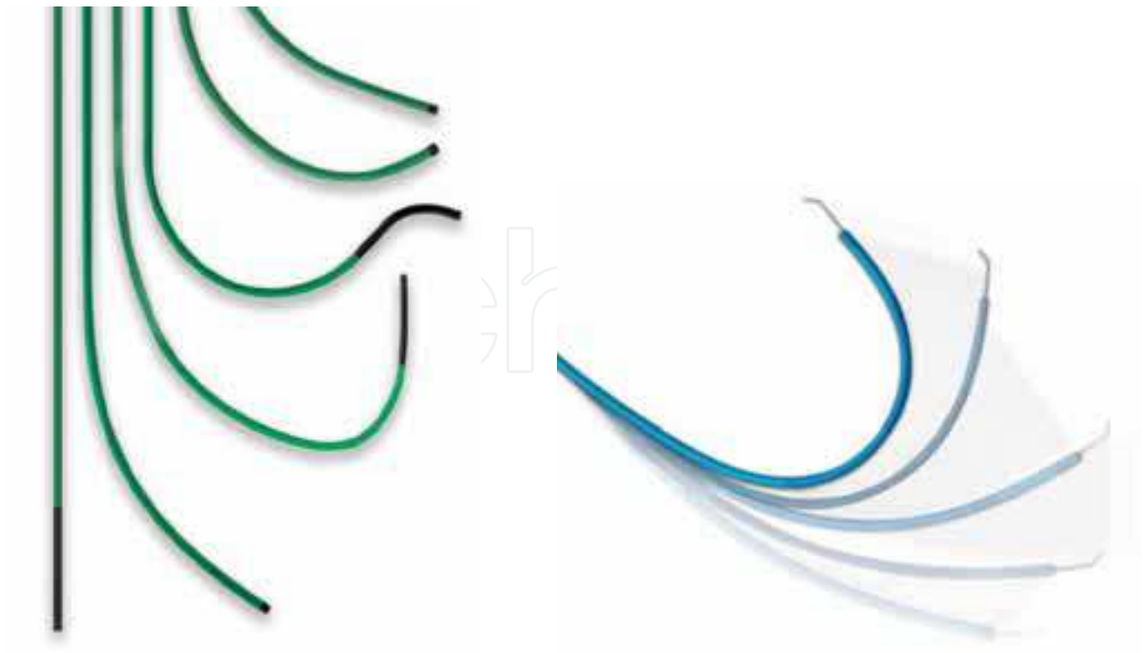


Fig. 1. Fixed curved and flexible guiding catheters (Courtesy of Medtronic Hungary)

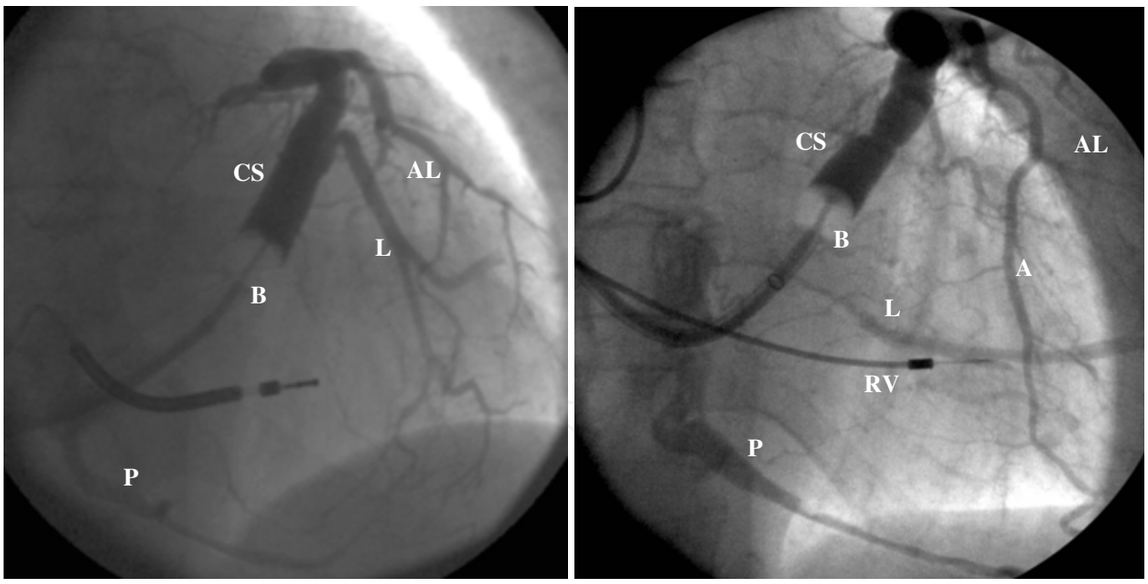


Fig. 2. Various coronary anatomies CS – coronary sinus, AL- anterolateral, A – anterior, L – lateral, P- posterior, RV – right ventricular lead, B - balloon

In patients with atypical anatomic variations or prominent Thebesian valve the use of a curved or steerable electrophysiology catheter inserted into the guiding catheter helps to cannulate the CS (Fig.3.). Intracardiac signals of the catheter help the orientation within the cavitiy of the atrium. Obligate atrial signals on the CS 1, 2 (distal electrode) show the proximity of the orifice. The catheter is advanced by simultaneous counterclockwise rotation and straightening of the catheter. The concurrent signals on the other CS electrodes prove

the achieved CS position (Fig.4). After the EP catheter is in the CS, the sheat is advanced until the tip of the catheter.

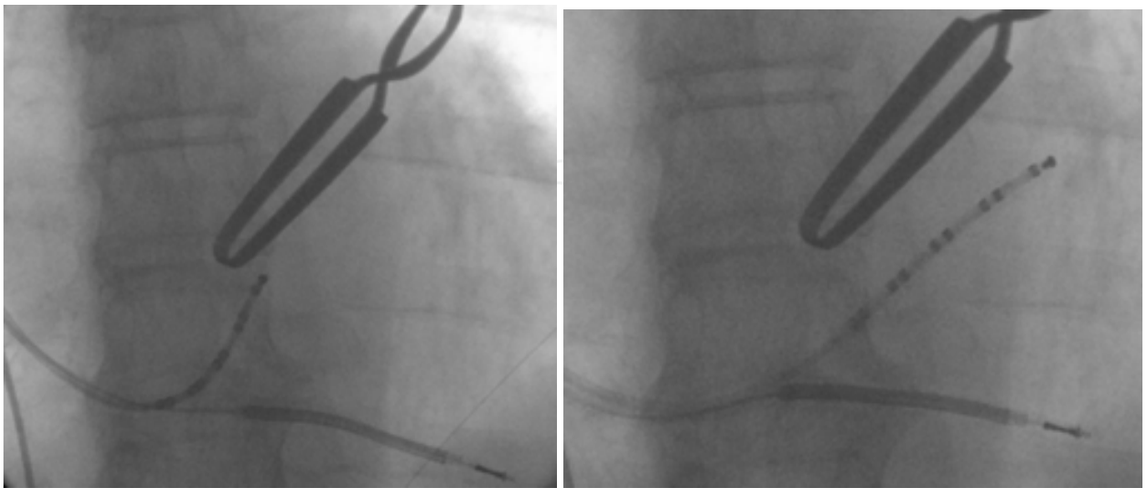


Fig. 3. EP catheter in the orifice of CS (left) and in the middle CS (right)

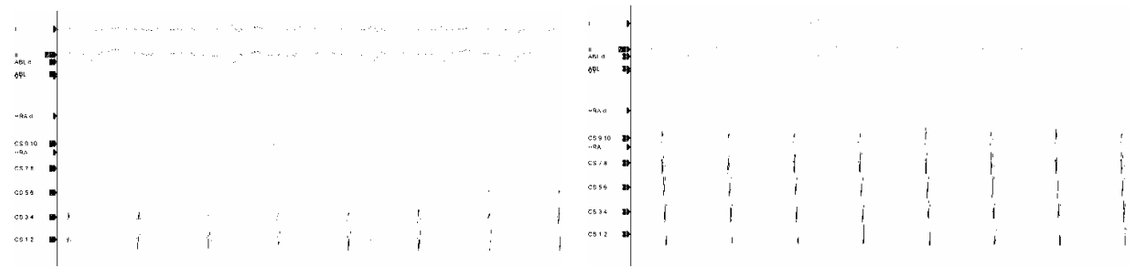


Fig. 4. EP catheter tip is near the orifice of CS (Left), EP catheter is inside the CS (Right)

Positioning the LV lead can be performed directly through the guide or with over the wire technique. The most common positions are the lateral or the posterolateral veins, which are sometimes difficult to access. Using different wires with different curves might help to navigate into the sidebranch. In cases when the sidebrach is visible, but the operator is unable to access with the wire, using different diagnostic catheters (eg.:Judkins Right 4 coronary, Internal Mammary catheters) might be useful.

2.3 Absence of lateral branch

The absence of visible lateral branch can occur when the inflated ballon is positioned distally in the CS. Pulling back and inflating the balloon at the orifice might show the origin of a posterior vein or sometimes separatly originating vein can be found (Fig.5.). A different preshaped fixed or a steerable catheter can find access to the vein. If the orifice is too wide for the occlusion balloon, advancing the balloon to the middle of CS and by givining contrast retrograde filling of the posterior vein can visualise the orifice of the vein.

If the sidebranches are not visible after reinflations of the balloon, the small vessel size tributaries deny the transvenous implantation, the transseptal approach can be continued immediatly or surigcal approach can be considered.

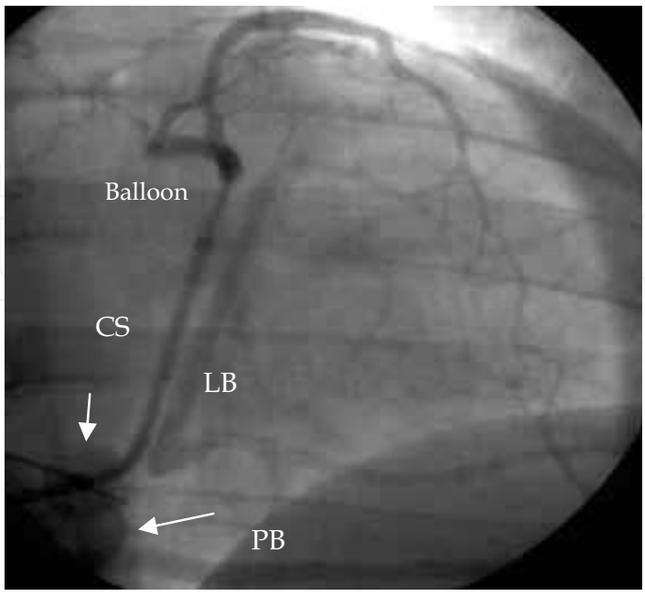


Fig. 5. Separatly originating vein: CS – coronary sinus, LB –lateral branch, PB- posterior branch, upper arrow – CS orifice, lowwer arrow – seperate posterior vein orifice

2.4 Intervention of the vein - Stenosis, sharp angulations, small vessel size or occluded sidebranches

Stenosis, sharp angulation, small vessel diameter of the sidebranch can be solved by predilatation of the branch with a balloon or stenting the proximal part of the branch using a coronary stent. After succesful balloon dilatation the venogram may confirm patent target vein. However the visual success is almost reached, in some cases the vessel is still not accessible. Often tortuous veins can be the cause of unsuccessful LV implantation (Fig.6.). Stiffer, more dangerous wires PT–2 and PT Graphix Extra Support (Boston Scientific, Natick, Massachusetts), *Jndo* and SV8 (*Cordis* Corporation, Miami, Florida) are recommended for experienced operators. Advancing the wires as far as possible around the veins anchores the system (Fig.6.). If the distal soft part of the wire is advanced through the stenosis or the angulation, the stiffer middle segment of the wire straightens the vessel and the lead can be inserted (Fig.7.). Pull-push maneuver, pulling the wire and simultaneously pushing the lead can also help to andvance the lead. The buddy wire is also an alternative technique to facilitate the lead positioning.

2.5 Venous valve in the sidebranch

Valves at the beginning of the tributaries can also present unexpected difficulties. In case of only one lateral sidebranch the delivery of the wire and the lead is the key to the success of CRT. The standard coronary interventional procedure ensures the performance. After crossing the leasion with a coronary guiding wire, a 2.0-2.5 mm diameter balloon is positioned and inflated between the valves (Fig.8.).

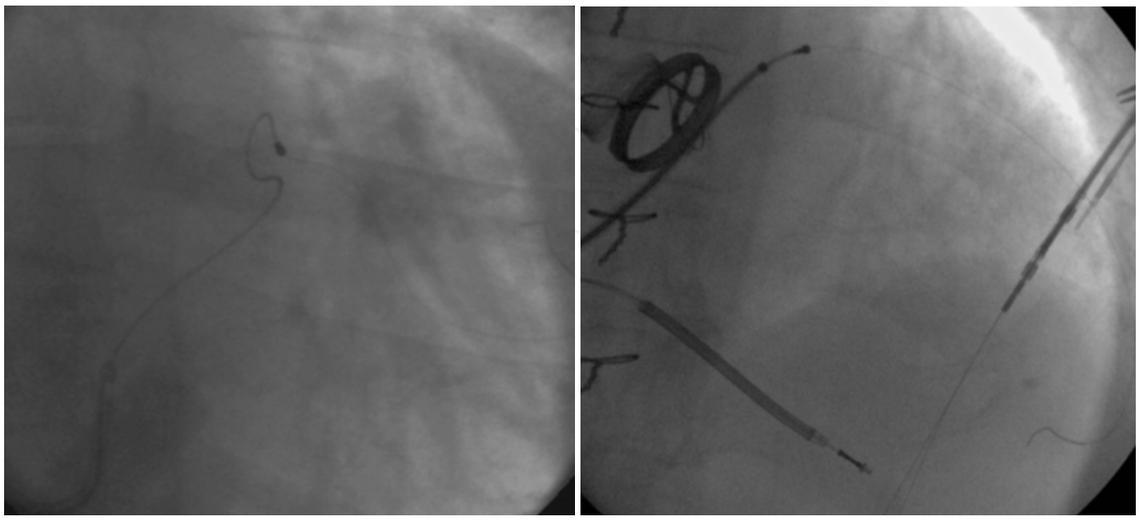


Fig. 6. Tortuous sidebranch (left), anchoring the wire, advancing over the apex (right)

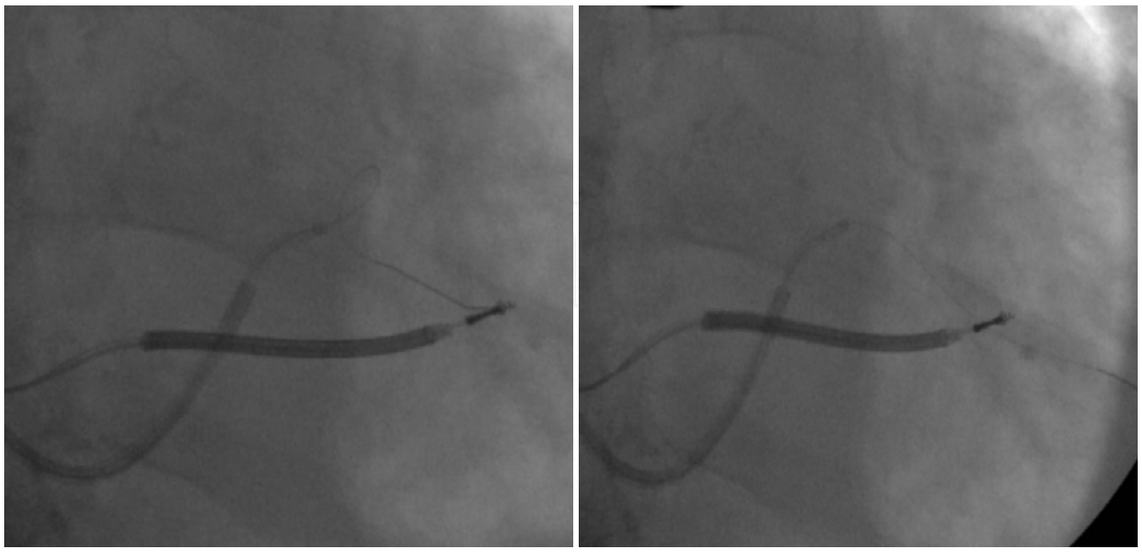


Fig. 7. Proximal kinking straighted with the advancement of the wire.

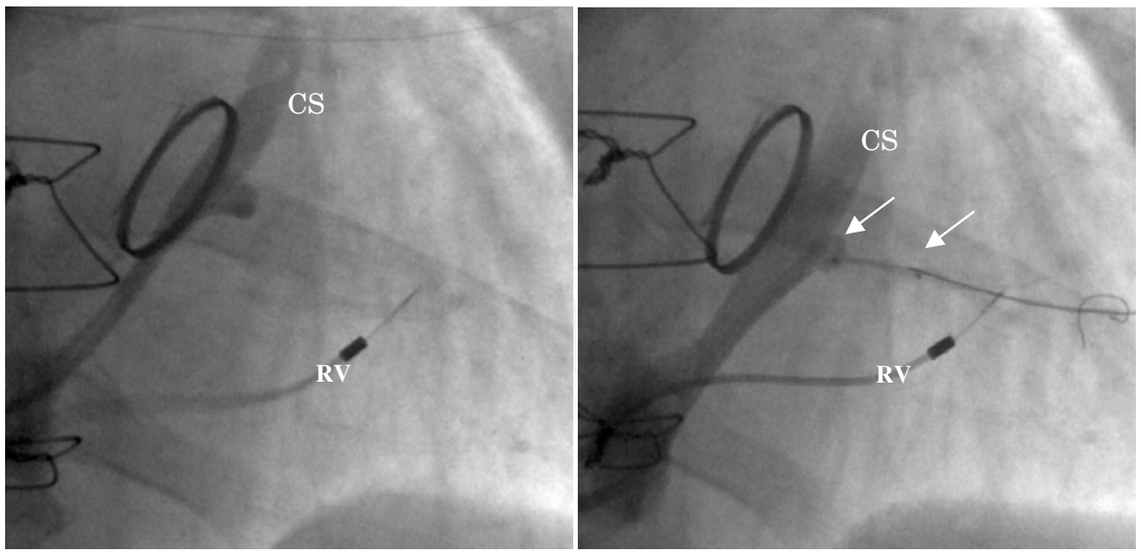


Fig. 8. Valve at the origin of sidebranch (left), Positioning the balloon with the help of buddywire; CS – coronary sinus, LB –lateral branch, RV – right ventricular lead, arrows – proximal and distal marker of the balloon)

Insuffitient results need further intervention, coronary stent deployment may be useful. The selection of the length is adjusted to cover the valves entirely. Moderatly oversized stent can ensure the free retrograde access over the valve (Fig.9.). Undersized or malappositioned stents cause difficult wire and lead delivery.

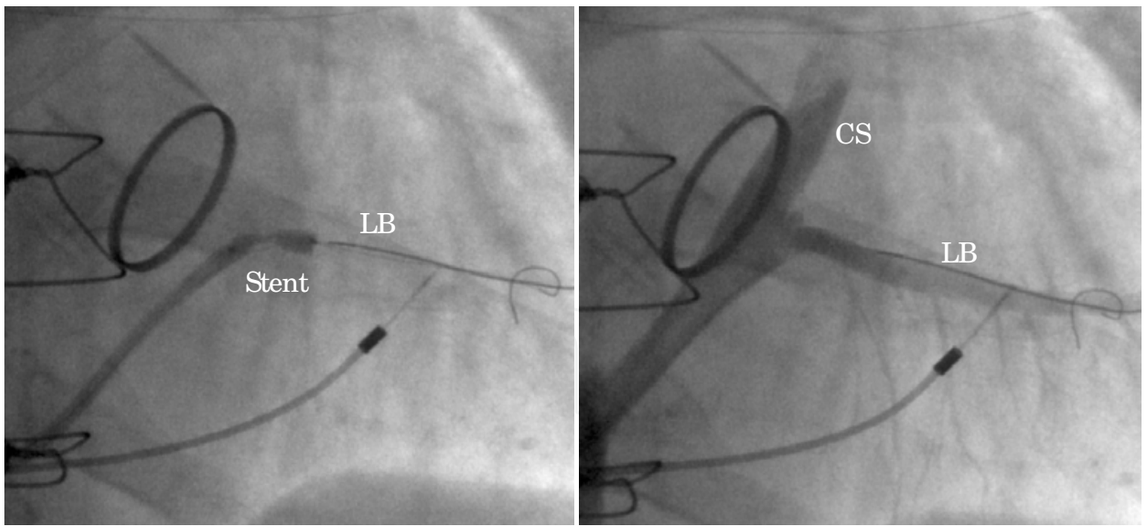


Fig. 9. Stent deployment (left), Contol venogram of the sidebranch (right); CS – coronary sinus, LB – lateral branch, RV – right ventricular lead

2.6 High ventricular pacing threshold or phrenic nerve stimulating, inability to fixate the lead

Finding the individual optimal site is always a task. After accessing the lateral vein with the LV lead, pacing threshold is measured. Scarred myocardial tissue and abundant fat between

the vessel wall and epicardium may increase the capture threshold. Chronic heart failure originates often from ischeamic heart disease, therefore scarred tissue is relavant component in high pacing threshold. When insuffitient pacing thresholds are measured in the target vein, sidebranches should be explored with a 0.014 inch coronary guidewire, and advancing the lead to the wedge position can bring success. Ultimately alternate vein should be searched. To reach everyones goal, the successful resynchronisation, higher thresholds are accepted at LV lead in case of effective resynchronisation. The phrenic nerve stimulation is the other limiting factor to reach the optimal site. Occurence of phrenic nerve stimulation while stimulating at the target position yields for alternative sidebranch. Minimal movements of the lead should be considered after implantation in stand up position. The optimal site for the individual is the latest contracting, optimal capture threshold site without phrenic nerve stimulation. Inability to fixate a passive fixation lead in this position can result in changing the lead to active fixation lead or stenting the lead (Fig.10.). Stenting during the first implantation (Szilagyi et al., 2007) can be a choice when macroscopic or microscopic dislocation occurs and there is no other suitable vein accessible or phrenic nerve stimulation is seen in stable anatomical position in the distal part of the side-branch and the lead needs to be fixed in the more proximal, wider, otherwise unstable parts of the target vein.

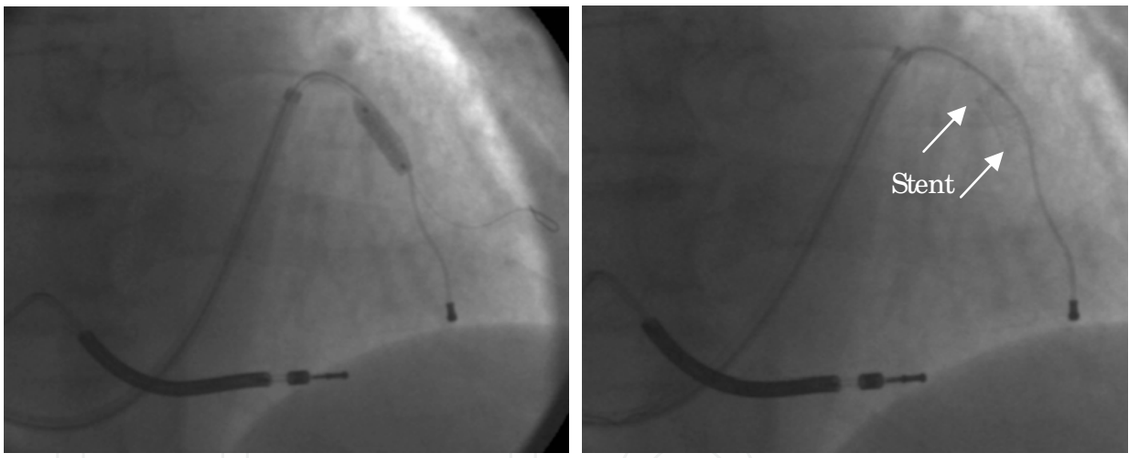


Fig. 10. Stenting of the lead (left), CS lead with the stent (right)

2.7 Recurrent dislodgement of LV lead - stenting

Despite continous technical development in the last few years, in the large CRT trials 5-10 % of patients required reoperation during follow up because of CS lead dysfunction. The stenting of the LV lead in cases of postoperative dislocation may be an effective and feasible alternative stabilising technique. Convetional wires, balloons and stents are used as in coronary artery interventions. The wall of the veins are thinner and more expansive, therefore the size of the stents are oversized with 20-30% of the vessel size and dilatation pressures are fit to reach the desired size. In our 5 years experience no rupture or any serious complications of the veins due to the stenting of the LV lead has been observed. Though it seems to be effective procedure, indiscriminate, reagular use is not recommended. Long term results are needed to prove the safety of this method.

2.8 Left ventricular leads

Unipolar and bipolar LV leads are available in different angeled, curved shape (Fig. 11., 12.). The industry is continously developing new designs to enhance the delivery and the stability of the leads. The operators selection is to find the best lead desing for the individual coronary sinus anatomy. Most of the leads have over-the-wire desings and the steroid-eluting distal tip provide better long term pacing parameters. Passive fixation leads have single or double angulations, helical shapes or silicon anchors, diameters range between 4-6 Fr. Deployable lobes of the active fixation leads can expand up to 24 Fr allowing stable lead positions. The biggest advantage of the active fixation lead is the 0% chronic dislodgement rate. This secure stabilization of the lead might only be disadvantageous in case of need of extraction.



Fig. 11. Unipolar, Bipolar, passive and active fixation leads (courtesy of Medtronic Hungary Ltd.)



Fig. 12. Bipolar, passive fixation leads (courtesy of Biotronik Hungary Ltd.)

2.10 Venous valve in the CS or severe kinking of the vein

Valves are commonly present in the main CS, but they are usually not recognized. We realize this as a problem, when crossing the valve with the sheath or the LV lead is very difficult (Fig. 13.). Severe tortuousity of the proximal CS can inhibit the advancement of the guiding sheat. Withdrawal of the tip of the guiding sheath more proximal from the valve enhance to find the way over the valve with a 0,014-inch guidewire. Individual formation of the tip of the wire might be necessary. After crossing the valve with a 0,014-inch guidewire, a second 0,035- inch wire should be advanced paralelly. If the second wire is able to cross the valve, predilatation of the valve on the 0,014-inch wire can secure the crossing. The outer diameters of the valves are similar to the main CS, therefore coronary interventional balloons similar to the size of the sheath will not harm the vessel. The purpose is to open the valve for retrograde wiring. If the valves still prevent the advancement, a second and third 0,035- inch guidewire should be inserted into the sheath to the distal CS. This will keep the valve open to the size of the sheath and the three identical wire anchores the system. Using the push-pull technique, pushing the

guiding sheath and pulling the wire, crossing can be achieved. This method is useful in case of tortuous and stenotic proximal CS (Fig. 13.).

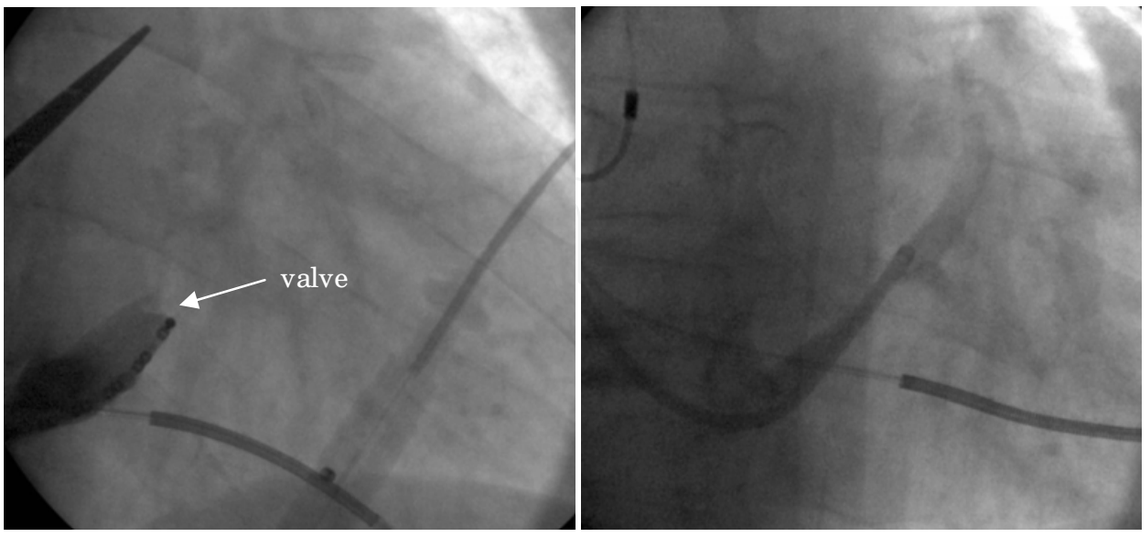


Fig. 13. Upsream occlusion of CS caused by valve in the proximal CS (left), Stenosis of the proximal CS (right)

2.11 How to avoid CS dissection, when to stop the procedure?

A rare, but potentially dangerous complication of the manipulation is the dissection of the CS (Fig.14.). Pericardial tamponade can be lifethreatening, though on the venous, low pressure side of the circulation contrast clouds seem to diminish between the epicardial space without any symptoms. Small amount of persistent contrast in the pericardium or in the myocardium can be followed with X-ray without clinical relevance.

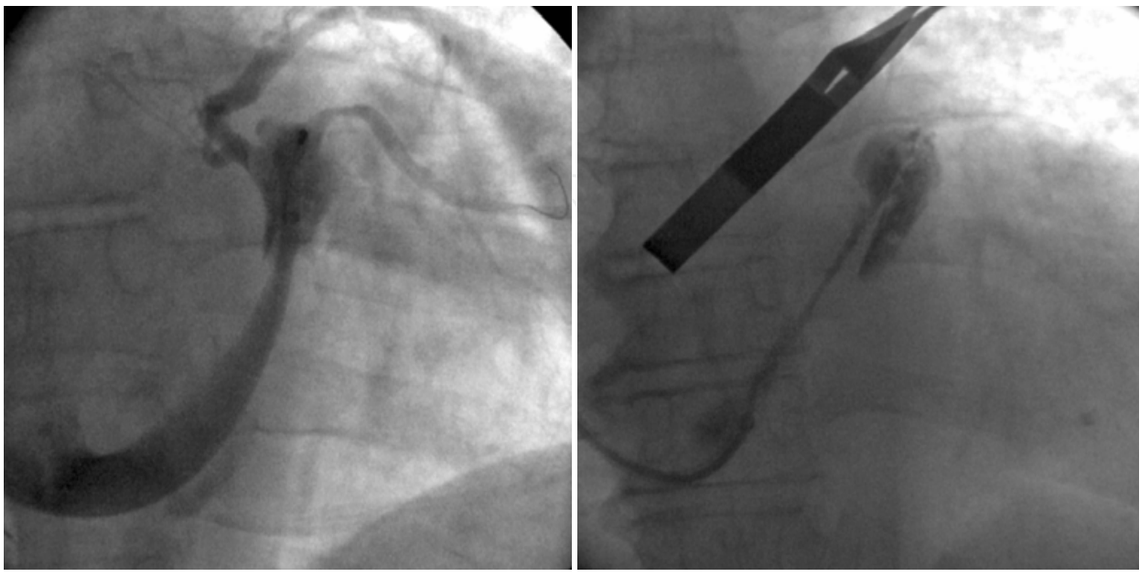


Fig. 14. Dissection of the CS by advancent of the sheath (left), Contrast cloud after positioning the occlusion balloon without a wire (right)

The availability of an intraoperative ultrasound is essential to provide the safety of the patient and to help the decision of discontinuation of the procedure. The completion of the implantation should be contiued as this might be the last chance of the LV lead positioning in the CS if there is no sign of tamponade and there is any chance of finding the CS lumen with a wire. In case of dissection over the wire lead insertion is recommended, after the wire ensures the intraluminal position of the tributary. The most often causes are the forceful or not paralel advancement of the guiding sheath or the occlusion balloon. Using a Jguidewire during advancement of the manipulating devices can avoid this complication. The pullback technique of the sheath can help to reach the desired site and injection of small contrast confirms the size and relation between the vein and the balloon as well as the proper position of the sheath in the CS.

2.12 CS myocardial bridge

Myocardial bridge is rare and caueses minor difficulty. This can be suspected when the lumen of the vein filled with contrast varies during the systolic and diastolic phase of the heart (Fig.15.). The problem can overcome by the advancement of the guiding catheter during diastolic phase of the heart cycle. The importance of using guiding wire is increased, because of the higher probability of dissection. The advancement should be in the diastolic phase. The use of occlusion balloon is discouraged, direct contrast filling can prove the tributaries.

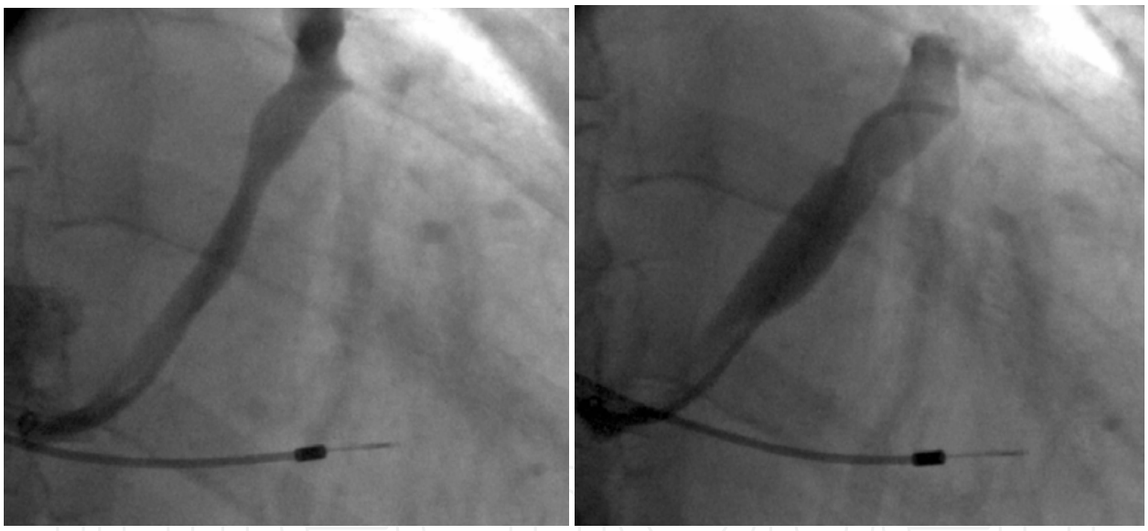


Fig. 15. Muscular bridge in systolic (left) and diastolic phase (right)

3. Reintervention of the LV lead

In a long term follow up 7 % of the transvenous LV leads needed reintervention (Borleffs et al., 2009). These median follow-up of 645 day data are not comparable with others usually terminated at 6 month. In this series 33% of the reinterventions were indicated after 6 months. Reoperation is an other surgical trauma for the patient and might have higher infection rates. Minimal invasive femoral approach technique is feasible and effective for the retraction of the LV lead from distal dislocation (Szilagyi et al., 2008). At reoperation original LV leads might need to be extracted. Passive fixation leads are usually extracted easily, no fibrosus adhesion complication occurs in the coronary sinus. No considerable data are

available for the extraction of the active fixation leads. In our limited experience in stented leads series, leads were always extractable when needed and minimal invasive retraction was able to perform in cases of phrenic nerve stimulation. At reoperation the original lead can be inserted to other sidebranch, or new passive or a new active fication lead can be delivered. At surgical approach where irreversible fixation of the lead was performed, reintervention can be solved only with implantation of a new lead. The surgical reoperation carries out further difficulties due to the adhesions, therefore in some surgical techniques at the first implanatation a second back-up lead is applied.

4. Transvenous endocardial pacing - Transseptal approach

Patients who are ineligible for surgical epicardial implantation and have no contraindication for lifelong oral anticoagulation can be selected for this approach. Advantage of this second line option is the same setting used for transvenous epicardial implantation, which makes it easy to convert the unsuccesful CS lead implantation to this rescue approach. The procedure does not require general anaesthesia and minimal postoperative recovery is needed. The significant physiological benefit of endocardial pacing compared to epicardial pacing during CRT was described in a series of 23 patients (Garrigue et al., 2001). The transseptal approach has been used for over 40 years for haemodynamic measurements, mitral and aortic valve angioplasty and in invasive cardiac electrophysiology for left sided accessory pathway ablations as well as for the isolation of the pulmonary veins. Therefore, there is little debate about the risks of the procedure with well experienced operators. However the major concern is about the long term risks of thromboembolic complication and mitral valve disruption or endocarditis related to permanent presence of the LV lead. The first case report was originally described using femoral transseptal puncture and a snare technique via the right jugular vein (Jais et al., 1998). The lead tunneled over the clavicle increases the risk for lead damage and skin erosion. Small modificatons were described until the recently applied techique was clarified (van Gelder et al., 2007).

The transseptal implantation begins with a standard transseptal puncture via the right femoral vein. After the successful puncture, controlled by the left atrial pressure curve, iv. 5000 IU of heparin is administered. The 0,035-inch guidewire is administered to one of the pulmonary veins and then the dilator and the sheath are removed. A 6-8mm wide balloon is inserted and dilated at the septal puncture site. In the guiding sheath a steerable electrophysiological catheter is avanced from the subclavian area towards the septum of the right atrium (Fig.16.).

The balloon is deflated and the EP catheter is advanced transseptally into the left atrium and then to the left ventrical. Holding the EP catheter in position the guiding sheath is forwarded to the left atrium (Fig.17.). The invasive pressures prove the proper localisation of the sheath. The optimal activation site is measured with the EP catheter. Standard bipolar leads are screwed into the desired location of the postero-lateral wall of the LV. Keeping a suffient slack in the lead, the proximal end is sutured in the pectoral region after pacing and sensing threshold tests and then the generator is connected (Fig.18.).

Postoperatively subcutaneous heparin is administered until the target (3,5-4,5) INR is accomplished with oral anticoagulant. Theoretically this might increas the risk of pocket haematoma.

In our practice we supplemented the transseptal technique with the recording of an electroanatomical map during the procedure (CARTO group, Biosense Webster, Diamond

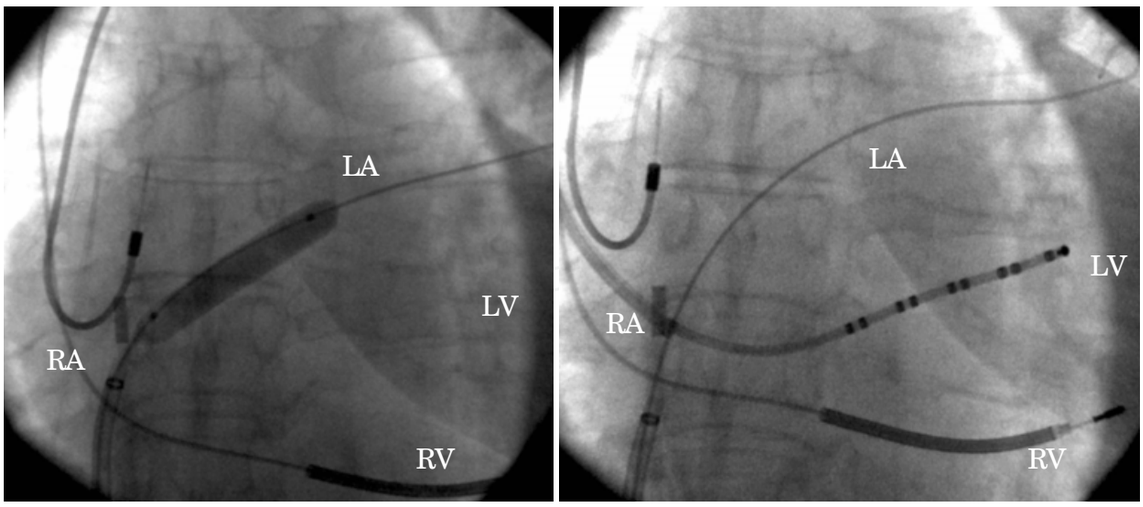


Fig. 16. Transseptal ballon dilatation (left), Advancement of the EP catheter to the left atrium (right)

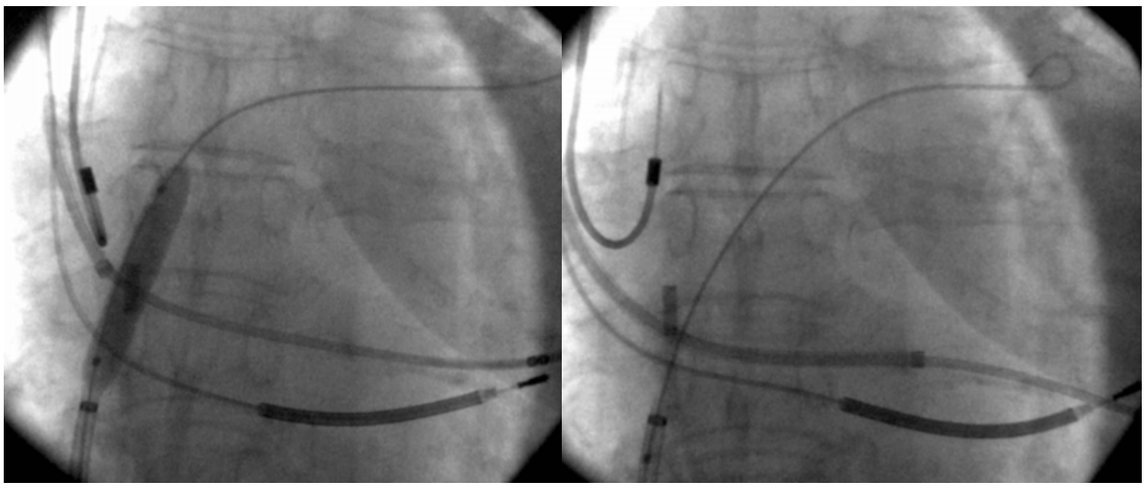


Fig. 17. After balloon deflation (left), the sheath is advanced transapically into the LV (right)

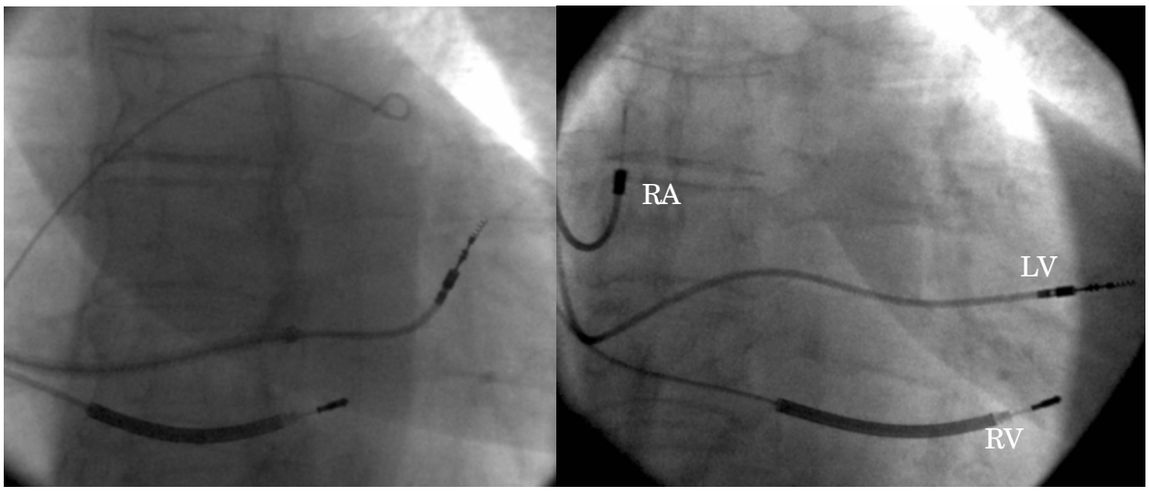


Fig. 18. Active fixation lead is positioned (left), Final position of RA, RVand LV leads (right)

Bar, CA, USA) to identify precisely the latest activated endocardial site of the lateral LV wall, concerning, that in our cases these were the last options for CRT. We used additionally intracardiac echocardiography (ICE) during the puncture and the dilatation of the atrial septum for safety reasons.
The main disadvantage of this technique is the unknown long term thromboembolic risk. While there are only small numbers of patients with endocardial LV pacing lead, we might accept that the risk similar as after mechanical valve implantation. Over an 85±5 month follow up of 6 patients, one patient had LV dislodgment at 3 months necessitating reintervention, later on no significant change in LV electrical parameters was observed. Five patients had thromboembolic event free period, however one patient had transient ischaemic attack whose anticoagulation was accidently interrupted (Pasquie et al., 2007).
This technique seems to be a feasible and safe second option with a benefit of endocardial pacing site. The possible disadvantage is the lifelong antiocagulation, the lead crossing the mitral valve and is inserted into the lateral wall, though no major complications due to this phenomena were published yet.

5. Open chest and percutaneous surgical epicardial approach

The fundamental invention, the first reported CRT implantation case (Cazeau et al., 1994) was described with epicardial LV lead and transvenous insertion of the right atrial and right ventricular (RV), left atrial stimulation was reached via the CS. In the early years, this approach was associated with considerable morbidity (Khan et al., 2009). After the beginning of the CRT era, several inventions were made to achive a more comfortable, feasable and safe procedure. All the other CRT techniques originate from this procedure to overcome the different limitations of the combined epicardial and endocardial lead implantations. The need of genearal anaesthesia, transeosophageal echocardiography controll during the operation, epicardial fat and fixating the epicardial lead on a moving target are disadvantages. The surgical trauma and the recoverey time is appreciably greater than the transvenous LV lead implantation. The most dangerous problem of the surgically implanted epicardial leads, usually used as a rescue technique, is the possibility of chronic increase of threshold, even the loss of permanent CRT. The different surgical epicardial lead implantation reports confirmed excellent long-term results on the basis of the 3 and 6-7 month follow up, but during the 1-5 year follow-up epicardial leads might have a significantly higher failure rate, than the CS leads (Lau, 2009). The benefit of this approach is the direct visual control of the latest contracting segment during the implantation, there is no limitation of the coronary venous anatomy for lead placement and the smaller incidence rate of lead dislodgment and phrenic nerve stimulation. Less flouroscopy and avoidance of intravenous contrast are also advantages over the transvenous approach. There are several currently used surgical approaches to implant the LV pacing leads: the full left thoracotomy with the widest accessibility of the free lateral LV wall, the minimal invasive limited left lateral thoracotomy with smaller postoperative pain and recovery time, the video-assisted thoracoscopy and the robotically assisted left ventricular epicardial lead implantation technique. After development and continous improvement of the transvenous LV implantation to the CS, the open chest access for the surgical epicardial lead placement has become a second line approach. Nevertheless at planned coronary artery bypass graft surgery, valve repair or replacement, epicardial surgical approach might still remain the first choice. The surgical implantation may be preferred in patients with congential heart disease, where the venous anatomy can interfere the transvenous approach.

5.1 Minimal thoracotomy

This epicardial LV lead implantation procedure is performed in an operating room, under general anaesthesia, single-lung ventilation and beating heart. Transeosophageal echocardiography (TEE) control is needed throughout the procedure. A 3 to 5 cm incision is made over the 4th or 5th intercostal space anterior to the midaxillary line. The lung is pushed back with a wet towel and the pericardium is opened anterior to the phrenic nerve. After mapping the left ventricle for optimal pacing site one or two epicardial unipolar or bipolar leads are attached to the target area with implantation tools (Mair et al., 2005). After testing the leads the capped terminal pins are tunneled submuscular to the provisional pocket and the pacemaker is then connected. A chest tube is required postoperativly and can be discontinuated within 48 hours. A recent investigation (Patwala, 2009) described this technique safe and acceptable option, but declaired to remain a second line procedure.

5.2 Video-assisted thoracoscopy (VATS) and epicardial lead implatation

This minimal invasive approach is a routine endoscopic procedure in thoracic surgery. It uses two or three incisions for the ports within the 4th or 5th intercostal space along the aterior and midaxillary line. General anaesthesia and single lung ventilation enables the deflatation of the left lung. The camera and the manipulating instruments are inserted through the different ports. Under visual control the pericardium is opened laterally to the phrenic nerve, the obtus marginalis as landmarks help to identify the desired site and an epicardial lead is screwed into the lateral wall of the LV. After TEE control and pacing threshold test the proximal end of the lead is passed through the medial incision and is tunneled subcutaneously to the pocket. The average operation time was reported 55±16 minutes (Gabor et al., 2005). The procedure is well tolerated, it has minimal postoperative recovery and a very good cosmetic results.

5.3 Robotically assisted left ventricular epicardial lead implantation

This is an emerging second line, effective technique performed with endoscopic assistace (DeRose et al., 2003). The daVinci Robotic Surgical System (Intuitive Surgical Inc., Sunnyvale, California) is composed of a surgeon control console and a surgical arm, that positions and directs the micro-instruments. The instrument is inserted into the chest cavity through two 8 mm ports and the endoscope is inserted through a third 10 mm port in the seventh intercostal space in the posterior axillary line. The surgeon controls the instruments away from the operating field and views the site through a magnified, real three dimensional eyepiece. Computer interfacing allows the scaled motion, eliminates tremor and provides incredibly accurate surgical precision. This technique also needs genearal anaesthesia, single lung intubation and TEE. The left and right arms are placed in the 5th and 9th intercostal space. The pericardium is opened posterior to the phrenic nerve and the region of the obtus marginals is identified to find the latest activating area with a temporary pacing electrode. Two leads are implanted, the second one is for back-up purpose. Both leads are tunneled to the axillar region and the active lead chosen by the best threshold result is connected to the pacemaker. The second lead is capped in case of need of future use. The chest tube for evacuating the air is removed and extubation is performed before leaving the operation room. After short surgical recovery time, the patients are usually discharged at the first postoperative day. Follow-up results of 42 patients comfirmes the operation time on the plateau of the learning curve at 45±13 minutes, while the 3 and 6 month clinical response was 81% and 70%. Three patients experienced loss of lead capture at 1, 9, and 14 months where the second lead had to be

activated (Joshi et al., 2005). This procedure comfirmed to be safe and effective allowing minimal invasive rescue therapy after failed transvenous CS lead implantation. Despite of all the benefits of this technique, the greatest disadvantage is the limited accessability and experience with robotic systems. Nowadays only few centres are able to perform the robotic technique with enough experience.

6. Transapical endocardial lead implantation

This new technique combines the minimal invasive surgical approach and the advantage of endocardial pacing. The transapical endocardial approach was invented for the patients with extensive epicardial adhesions, which disabled the epicardial lead implantation (Kassai et al., 2008). Under general anaesthesia, selective bronchial intubation, after transthoracic echocardiographic location of the LV apex, an infraclavicular pocket and a small left thoracotomy is performed. The apex of the left ventricle is punctured and with a Seldinger technique an active fixating lead is inserted into the cavitiy of the left ventrical (Fig. 19. A, B). The bleeding is controlled with purse-string sutures. The guidance of the lead is achieved with a Jshaped guide wire under flouroscopy (Fig. 19. C).

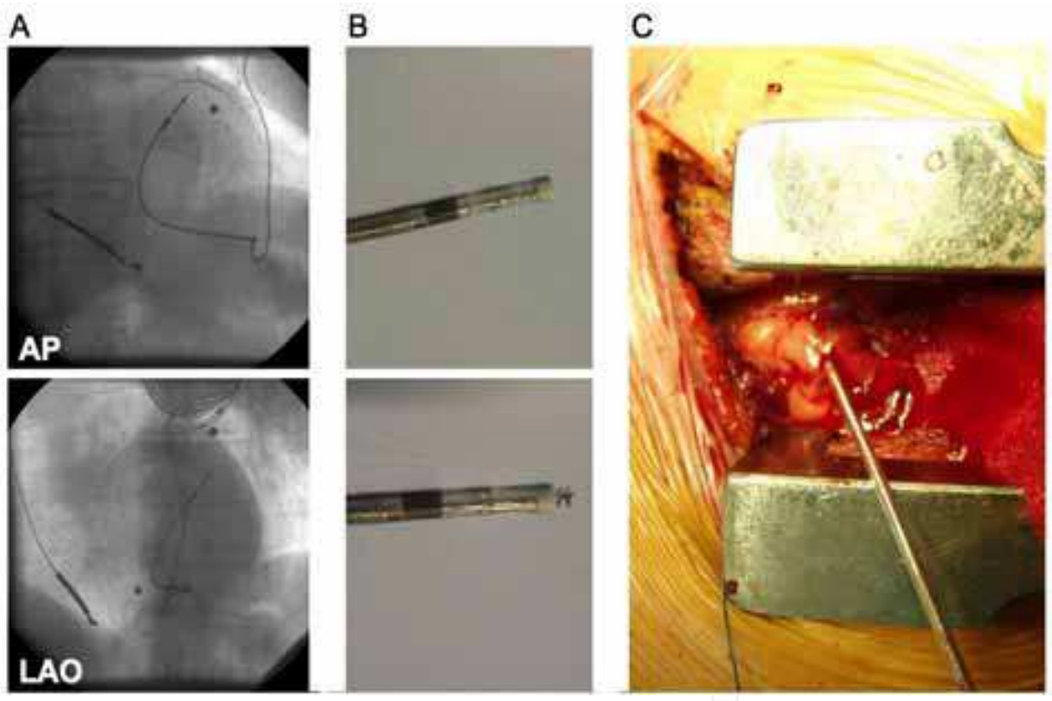


Fig. 19. A. AP and LAO projection of the LV lead, B. Tip of the active fixation lead, C. Intraoperative picture of the apex of the heart with the endocardial lead. (with permission from Kassai)

This allows wide range of manipulation of the lead in the LV cavitiy to find the latest activating, optimal segment. The transapical endocardial lead implantation does not involve the mitral valve, therefore the risk of mitral valve endocarditis is reduced. The lead is conducted into a subcutaneous tunnel up to the pocket of the previously implanted device. Oral anticoagulation is essential, the recommended INR level is identical to other mechanical prothesis.

The advantage of the this technique is the best accessibility of the endocardial segments without the limitations of the anatomy of the tributaries of CS or the surgical difficulties to reach the most delayed segment of the lateral wall. Phrenic nerve stimulation has not been observed. Though this technique is minimal invasive, the need for general anaesthesia and cardiac surgent is fundamental. The risk of oral anticoagulation and thromboemolic complication is thought to be identical to other mechanical valve prothesis or the transseptal endocardial CRT system. The limited experiences (Kassai et al., 2009) restrict this technique as a last resort where other CRT implantation techniques fail.

7. Conclusion

Event though various techniuqes are described to facilitate the LV lead delivery and positioning, the increasing number of CRT continues to pose numbers of challenging cases. The first line approach remains the transvenous epicardial technique with the interventional supplements and with the limitation of the coronary venous anatomy. Alternative approaches remain for the second line options. Incrased experience can help the implanter to choose the best second approach. Surgical access is commonly used, while transseptal and transapical endocardial lead implantations are in the learning curve phase. Stenting of the electrode using a coronary stent might be an effective method to prevent dislocation or phrenic nerve stimulation for selected patients. The possibility of the need of lead extraction should be considered during the selection of the approach. Further research and exprience is needed for the safety and long term efficacy of the alternative techniques.

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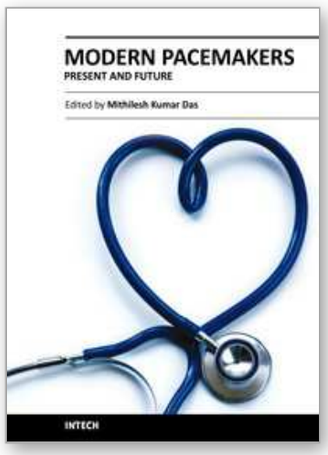
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Modern Pacemakers - Present and Future

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The book focuses upon clinical as well as engineering aspects of modern cardiac pacemakers. Modern pacemaker functions, implant techniques, various complications related to implant and complications during follow-up are covered. The issue of interaction between magnetic resonance imaging and pacemakers are well discussed. Chapters are also included discussing the role of pacemakers in congenital and acquired conduction disease. Apart from pacing for bradycardia, the role of pacemakers in cardiac resynchronization therapy has been an important aspect of management of advanced heart failure. The book provides an excellent overview of implantation techniques as well as benefits and limitations of cardiac resynchronization therapy. Pacemaker follow-up with remote monitoring is getting more and more acceptance in clinical practice; therefore, chapters related to various aspects of remote monitoring are also incorporated in the book. The current aspect of cardiac pacemaker physiology and role of cardiac ion channels, as well as the present and future of biopacemakers are included to glimpse into the future management of conductions system diseases. We have also included chapters regarding gut pacemakers as well as pacemaker mechanisms of neural networks. Therefore, the book covers the entire spectrum of modern pacemaker therapy including implant techniques, device related complications, interactions, limitations, and benefits (including the role of pacing role in heart failure), as well as future prospects of cardiac pacing.

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