Review Article
DOI: 10.5455/amaj.2016.01.003

Technical Review On Phrenic Nerve Stimulation During Biventricular Pacing – How To Avoid And How To Treat?

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Phrenic nerve stimulation (PNS) is one of the undesired complications associated with left ventricular stimulation. Absence of PNS during implantation procedure does not guarantee its absence in the future. It is may be managed with reprogramming but sometime it may necessitate repositioning of lead either with percutaneous or open surgical approach. The aim of this review article is to discuss peri and postprocedural management of patients with PNS. Here we also present data on frequency and management of PNS at our Institution.

Keywords: biventricular pacing, phrenic nerve stimulation

Introduction

Biventricular stimulation is one of the essential tools in the management of sympthomatic heart failure. Phrenic nerve stimulation with subsequent diaphragmatic contraction is one of the frequent complication associated with left ventricular stimulation via branches of coronary sinus and may be observed with it's frequency varying between 3 and 20 % of patients [1]. Some of patients with PNS can be managed by reprogramming of stimulation parameters, however some of them must undergo lead repositioning procedure. In this review article we aimed to present our own data and also to discuss methods that may help to avoid PNS and management of this complication. This will be discussed, in four different sections such as 1) peri-procedural considerations 2) postprocedural reprogramming for management of PNS, 3) selection of percutaneous or surgical approach for repositioning of left ventricular lead and 4) our own data and observations.

Peri-procedural Considerations

One of the important first steps during the procedure is to obtain coronary sinus venograms in all available views (AP, RAO 30, LAO 30) and to keep this data. In case of need for repositioning in the future, operator will be able to decide whether to proceed with percutaneous or surgical approach.

Any muscle relaxants and curarizing agents should be avoided in patients, who require periprocedural general anesthesia.

Implantation procedure is always performed in supine position and this ameliorates PNS and makes patient to sense it much more weaker that he or she will sense it in the upright position. For this reason, after implantation of left ventricular lead pacing at high output should be performed to evaluate presence of PNS, and in case of it lead should be repositioned if possible. In case of absence of alternative side branch lead should be withdrawn to more basal part of left ventricle, because more apical locations are more frequently associated with PNS. Operator should look for a small side branch within the target vein, where it could be possible to stabilize led. If it is also impossible and stable position could not be achieved, active fixation lead (Attain Starfix®4195, Medtronic, MN, USA) should be preferred. However at sometimes, and it is not so infrequent, proximal portion of target vessel tends to be widened and this precludes implantation of even this above mentioned active fixation lead. This is more

frequently observed in inferolateral vein, when compared to lateral and anterolateral side branches. In this situation, operator should look for another target site, or use newly introduced lead (Attain Ability®4196 Medtronic MN, USA), which has two electrodes, with interlectrode distance of 21 mm. It allows separate pacing from each of these two electrodes. So when pacing from distal electrode results in PNS, then device can be reprogrammed to pace from proximal electrode.

Previous studies performed with passive configuration LV leads showed no difference in frequency of PNS between various manufacturers and models [2, 3]. However it can be speculated that newer designs may result in decreased frequency of PNS.

Post-procedural Reprograming For Management Of PNS

The easiest way of management of PNS is decreasing pacing output. However this may also result in failure of LV capture, or PNS may continue despite absence of LV capture. This is frequently observed in patients with high ventricular pacing thresholds. For this reason, if PNS when pacing at high output is an unavoidable during implantation procedure, sites with lowest pacing threshold should be preferred.

New CRT systems have capability of programming of multiple LV pacing configuration. One recent study compared frequency and management strategy in patients with new and older models of CRT devices [3]. PNS was observed in 12 % of study group(new generation device) and 24 % of control group (old generation device). They observed that PNS was easily managed by reprogramming of new generation devices, however all patients with old generation devices had to undergo repositioning procedure.

Reprogramming includes several approaches, and all of these approaches should be tried before attempting re-operation. This include:

1. Decreasing of pacing output
2. In patients with true bipolar left ventricular leads one may try to use the tip or the ring/coil of the lead as either cathode or anode. Mechanism by which, configuration of left ventricular pacing results in decreased pacing threshold is not clearly understood, but it is suggested that this phenomenon occurs as a result of change in magnitude of current flowing through an excitable myocardial mass between electrodes (current density theory) [4]. Another important underlying mechanism is change in myocardial fiber orientation in relation to the electrical pacing vector. This theory is supported by observation, that stimulation threshold is lowest, when the stimulating electrical field is parallel to fiber orientation [5].
3. It was suggested that increasing of pulse duration during left ventricular stimulation could help to overcome PNS. This was related to different excitability properties of left ventricle (LV) and phrenic nerve (PN). One study investigated this relationship, and compared excitability properties (rheobase and chronaxie) of LV and PN in 44 patients with biventricular devices (Roka A, Szilagyi S, Geller L, Merkely B, Zima E. Prevention of diaphragm stimulation during biventricular pacing with long left ventricular pulse. Abstract of this study was presented at World Congress on Heart Disease which was held on July 26-29 2008 in Toronto, Canada). And they found that LV chronaxie was longer and its rheobase was lower, when compared to PN. With prolonging of LV pulse duration with setting of pacing output at twice of the threshold value, they achieved elimination of PNS in 5 of 6 patients. This approach seems logical and should be tried in every patient presenting with PNS.
4. Changing LV-RV pacing sequence (V-V delay) may also be of value in selected group of patients. We for the first time observed and report here beneficial effect of this approach in one of our patients with PNS. However, it should be noted that this may result in inappropriate hemodynamic response, and echocardiographic evaluation should be performed in these cases to avoid decline in cardiac output and subsequent deterioration of heart failure symptoms. Mechanism underlying this observation is not clear.

Selection of Surgical Or Percutaneous Approach For Repositioning of LV Lead

When all attempts of reprogramming failed, repositioning or reimplantation of lead should be performed. As we mentioned before, images of coronary sinus venogram with inflated balloon catheter should be obtained in all cases during initial implantation procedure. Pacing values and information about presence of PNS in any of side branches where measurements were made should be also noted on a separate procedural sheet. Based on these findings, one may decide whether to proceed with surgical implantation or percutaneous repositioning. In patients with leads positioned in the basal part of LV wall and no alternative side branches it seems better to proceed with surgical implantation.

When patient has an alternative side branch it is reasonable to try the second procedure of implantation using the same technique used during initial procedure.

When pacing lead moved distally in to the vessel or when it is somewhere in the middle wall good results can be achieved by slight withdrawal of lead in more basal position. But one must be careful when withdrawing active fixation lead, because it may cause dissection and perforation of coronary sinus.

Another technique that may be used in patients with the only one enlarged vein and apical displacement of LV lead, is stenting of coronary side branch when lead placed in a desired position [6, 7]. This will result in stable position of the lead. This procedure may be performed either by subclavian approach or recently introduced femoral approach [8]. During femoral vein approach, ablation catheter and Amplatz 2 left type guiding catheter must be introduced to the right atrium. This is followed by cannulation of coronary sinus with Amplatz catheter, and advancement of guide wire and stent to desired vein. Stent size should be selected according to reference vein diameter. Because of the presence of enlarged vein, stents suitable for coronary intervention may not suffice and larger diameters stents, ahich are used in peripheral arterial intervention should be available. Then ablation catheter must be looped around the LV lead in right atrium, and slightly withdrawn until lead positioned in

desired position. Stent should be inflated only when all the measurements confirm desired location. These technique was successfully performed all nine patients included to this study. The advantage of this technique is obviating need for reoperation of generator pocket, which may increase risk of pocket infection, and other related complications. Another advantages is less invasive nature and shorter duration of hospitalization. It may be used more successfully if the LV lead is displaced in a distal position, but one must be careful to avoid displacement of right ventricular an/or atrial lead during the procedure. However it should be noted, that stabilization of coronary sinus lead with stenting, makes it impossible to extract this lead in the future, and patients should undergo surgery. This is the most important disadvantage of this procedure. Implantation of active fixation screw-in leads was suggested as alternative for stenting within coronary veins, however safety concerns of this technique are still exist [9].

When all percutaneous approaches fail, patient must be referred for surgical placement of left ventricular lead. Surgical techniques are out of the scope of this review, but we think that it is important to mention here that favorable hemodynamic results can be achieved with posterolateral approach, rather that standart lateral thoracotomy, and special attention should be given here to appropriately localize phrenic nerve, and this is especially important in patients with PNS.

Conclusion

PNS is one of the frequent complications associated with biventricular stimulation. It has negative psychological effects, and may result in failure of biventricular pacing. Its management includes both, simple reprogramming and complex interventional or surgical procedures. In this review article we presented currently available scientific data on prevention and management of this clinical entity and presented our own point of view, experience and observations.

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