# Left Bundle Branch Pacing: A Perfect Compromise?

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Historically, pacing from the right ventricular (RV) apex has been the favoured approach to treat patients with bradyarrhythmia. RV apical pacing has generally been considered as a reliable technique that is well tolerated, safe and effective. However, this paradigm has been seriously challenged because of the detrimental consequences of long-term RV apical pacing. The need for a better pacing solution has paved the way to the quest of conduction system pacing (CSP).

## RV Apical Pacing

Evidence is overwhelming regarding the deleterious physiological and clinical effects of RV apical (RVA) pacing. Pacing from the RV apex induces abnormal electrical activation and mechanical contraction of the ventricles with interventricular and intraventricular dyssynchrony.

Long-term RVA pacing may result in left ventricular (LV) remodelling, micro-architectural alterations and myocardial perfusion abnormalities. These adverse effects have been related to reduced LV function and perturbed cardiac haemodynamics.[1] Clinically, RVA pacing is associated with increased risks of atrial fibrillation, pacing-induced cardiomyopathy, hospitalisation for heart failure and mortality.[2,3]

Importantly, these deleterious effects do not occur equally in all patients. RVA pacing-induced cardiomyopathy can manifest in different ways over a wide clinical spectrum, from asymptomatic subclinical LV remodelling to worsening pre-existing cardiomyopathy or *de novo* congestive heart failure with LV dysfunction. No clear model to predict individual susceptibility has been validated.

## Alternatives

Several alternatives have been put forward to circumvent the adverse effects of RVA pacing.

Algorithms to minimise RV pacing have been developed to promote intrinsic atrioventricular (AV) conduction. Although efficient at reducing the ventricular pacing burden, these algorithms have failed to improve clinical outcomes and, at times, can be proarrhythmic.[4]

Pacing from the RV septum or the RV outflow tract have been explored, but results remain conflicted and no clear clinical benefit has been observed.[5]

Cardiac resynchronisation therapy (CRT), achieved with biventricular (BIV) pacing, has unequivocally demonstrated its superiority over RVA pacing for patients with heart failure (HF), severe LV systolic dysfunction (ejection fraction (EF) <35%) and significant intraventricular conduction delay.[6] Nevertheless, despite refinement of patient selection, device and lead technology, approximately 30% of these patients do not show improvement with CRT.

BIV pacing is beneficial in patients with symptomatic HF, mild LV systolic dysfunction (EF<50%) and a high expected pacing burden (>40%).[6] The benefit of BIV pacing in these two populations may be only a lesser evil compared to RVA pacing. BIV CRT is achieved using the fusion of two non-physiological wavefronts between RV endocardial depolarisation (RV lead) and epicardial LV depolarisation (coronary sinus lead) to improve ventricular synchronisation. It does not re-establish normal physiology and will always remain a source of significant ventricular electromechanical dyssynchrony.

## Conduction System Pacing

CSP is the ideal approach to preserve normal ventricular electromechanical synchrony and haemodynamic physiology. Therefore, it has the potential to avoid the deleterious effects of RVA pacing.

Moreover, CSP can normalise bundle branch block (BBB). The longitudinal dissociation of the His bundle fibres theory most probably accounts for this phenomenon.[7] BBB is typically in the proximal His region, and pacing distal to the site of the block results in recruitment of the conduction system. Another explanation is virtual electrode effect wherein pacing at a higher output proximal to the block may overcome the block by capturing distal conduction fibres.

CSP has been shown to provide superior CRT compared to BIV pacing.[8]

## His-bundle Pacing

His-bundle pacing (HBP) is, unquestionably, the ultimate physiologic pacing approach to provide complete ventricular synchrony. Accordingly, HBP has been shown to be better at preventing pacing-induced cardiomyopathy and heart failure hospitalisations than RVA pacing.[9]

HBP has also been shown to reverse pacing-induced cardiomyopathy in patients with chronic RVA pacing and be beneficial for patients with CRT indications. It significantly reduces QRS duration when baseline BBB is present and improves LVEF and clinical status in patients with heart failure.[10,11]

However, despite decent overall success rates and favourable clinical outcomes, the initial excitement has led to significant scepticism owing to several inherent limitations. The His bundle is a small, cylindrical structure with significant anatomical variations relative to the triangle of Koch and the septal tricuspid leaflet.[12] Therefore, HBP requires a longer learning curve and success rates vary according to the experience of the centre. The overall success rate is approximately 85% but decreases significantly in the presence of advanced AV conduction disease.[13,14] The low R wave amplitude may result in atrial or His oversensing and ventricular undersensing.

Long-term success is also undermined by several factors. As the His bundle is encased by the central fibrous body, higher pacing output is required in 25–30% of cases at follow-up.

The high capture threshold, either at implantation or during follow-up, is unpredictable and of major concern. First, it can cause loss of His bundle capture, resulting in myocardial septal pacing in 9–17% of patients. Second, unacceptably high thresholds lead to an increased number of lead revisions in up to 11% of patients. Finally, when a lead revision is not deemed necessary, the higher output required can lead to premature battery depletion and increased frequency of generator change procedures.[15,16]

## Left Bundle Branch Area Pacing

Left bundle branch area pacing (LBBAP) has emerged as an enticing solution to the limitations of HBP. This is largely explained by favourable anatomical and histological characteristics.

The left bundle branch (LBB) is surrounded by dense myocardial tissue and offers a larger target zone for pacing owing to its thick, band-like structure. Moreover, the LBB can be recruited from the main trunk, the posterior fascicle or the septal fascicle.[12] Therefore, LBBAP is technically easier with a relatively shorter learning curve.

Enlarged right cavities and interventricular septum fibrosis are two technical hurdles occasionally encountered during implantation. Procedural success rates are high, even in the presence of intraventricular conduction disease.[17–20]

LBBAP provides stable and reliable lead parameters with longer battery life at short and intermediate follow-up.[17,18] The need for a back-up RV lead is abolished, and device programming is simplified.[21] Importantly, complication rates remain low with LBBAP. Increased threshold at follow-up is unusual and lead revision is hardly ever necessary.

Septal perforation rarely occurs but remains a concern. It is usually observed intraoperatively and is not associated with major adverse events when the lead is appropriately repositioned.[17,18] Long-term follow-up on lead performance and issues related to transvenous lead extraction are questions that remain to be answered in the future.

Pacing from the LBB does not result in complete right bundle branch block but rather in right bundle branch conduction delay with a relatively narrow QRS, suggesting mild interventricular dyssynchrony. Limited studies suggest that inter-ventricular dyssynchrony might have fewer deleterious effects than intraventricular dyssynchrony.[22,23] Therefore, whether RV activation delay during LBBAP is of clinical importance remains to be determined and will require further study.

Of note, bipolar pacing with anodal capture of the RV septum might be a potential avenue to attenuate interventricular synchrony. Adequate AV delay programming allowing fusion with native right bundle branch conduction is another option.

LBBAP preserves intraventricular LV mechanical synchrony comparable to that from HBP or native conduction.[24,25] In patients with heart failure and LBBB, LBBAP improves intra- and interventricular synchrony and is associated with a similar QRS duration reduction and LVEF improvement to HBP.[26–27]

LBBAP is promising as a future alternative to standard BIV CRT. It achieves CRT with high success rates, significant QRS duration reduction, LVEF increase and clinical status improvement.[20]

LBB pacing (LBBP) is defined as capturing the LBB either selectively or non-selectively (with LV septal capture). LV septal pacing (LVSP) occurs when only septal myocardium is captured without engaging the LBB. LBBAP encompasses both entities. LVSP activates both ventricles with delay, resulting in relative interventricular synchrony; it does not provide intraventricular synchrony, however.[28]

Criteria defining LBBP have been described, although differentiating non-selective LBBP from LV septal pacing can be challenging at times.[29] We believe that effort should be made to ensure LBB capture when physiological CSP is sought. New criteria have been published recently and should help to refine our definition of LBBP.[30]

## Have We Reached a Perfect Compromise?

HBP has been described more than 20 years ago, yet the quest for ideal CSP remains unachieved. Although appealing, HBP comes with numerous problems that are probably irreconcilable. Without significant change, HBP is condemned to remain limited to a handful of highly experienced implanters and centres.

As evidenced by the astonishing number of publications over the past years, LBBAP has gained significant interest and our knowledge is rapidly evolving. It is now established that LBBAP is feasible, effective, safe and provides reliable long-term lead parameters. Moreover, descriptive studies suggest advantageous surrogate and clinical outcomes.[17,18,20]

LBBAP has the 'disadvantage' of selectively engaging the LBB and delaying RV activation. This concession might in fact be the best thing that could have happened to CSP. By pacing downstream in the conduction system, away from the anatomically and histologically hostile His bundle region, LBBAP circumvents HBP's greatest limitations. The price to pay seems reasonable. LBBAP-induced RV activation delay appears to be marginal, especially with adequate device programming. We acknowledge that the clinical impact of this remains to be clarified, although no deleterious signal has been identified so far. This 'disadvantage' is at the heart of LBBAP's success, and we believe it might be the key to finally consolidate CSP into routine clinical practice, making LBBAP a perfect compromise. ❑

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