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Current research on the relevance of electrocardiography in cardiac resynchronization therapy

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In this issue of the EP update, we have summarized the recent research pertaining to electrocardiographic (ECG) findings in relation to management and outcomes of the cardiac resynchronization therapy (CRT).

Trying to identify responders among those with LBBB morphology

Even among those with true left bundle branch block (LBBB), about a third do not have a favourable response to cardiac resynchronization therapy (CRT). Thus all LBBB are not created equal and the pattern may be due to factors beyond delayed electrical activation (hypertrophy, dilatation, scar, isolated fascicular block). While a more strict definition of LBBB has been recently proposed [1], others have not found it correlating with electrical delay in the lateral wall. Risum et al. [2], investigated in a prospective observation study whether combining ECG criteria of LBBB with classical findings of electrical delay in lateral wall on 2D speckle tracking strain echocardiography (LBBB contraction pattern) improved the prediction of outcomes after CRT implantation. Only 30% of those with LBBB and QRSd between 120 and 150 ms had typical LBBB contraction pattern, while 65% had this pattern above QRSd of 150 ms. LBBB contraction pattern was an independent marker for future events, and had predictive power incremental to QRS duration and underlying cause of cardiomyopathy. Analysis in relation to strict LBBB criteria and conventional echocardiographic indices of dyssynchrony did not yield any further benefit. Thus it appears that investigating LBBB contraction pattern in those with QRSd 120-150 might help in choosing those who might not benefit from CRT. However the parameters used are semi-objective and might be difficult to reproduce among different machines and centres, besides getting confounded by scar burden and location. However it is likely that with advances in automated algorithms, myocardial imaging may again become an integral part of work up for CRT.

Outcomes of CRT in relation to changes in post-implantation QRS morphology

Narrowing of QRS duration after CRT implantation has been taken as a reasonable marker for ventricular resynchronization. Yang et al. [3] hypothesised that ventricular remodelling and improvement in echocardiographic parameters are likely to be accompanied by reversal of electrical dyssynchrony in the ECG as well. This was measured by recording and comparing the pre-implantation ECG to the native QRS beats post implantation after transient switching off of pacing. A total of 74 patients were studied of which 47% had LBBB. At follow-up of 18 months, authors found that Δnative-QRSd (pre QRSd-unpaced QRSd at follow up) was the single most important ECG marker for identifying responders and those with favourable anatomical remodelling. Patients with Δnative-QRSd > 0 ms had higher increase in absolute LVEF (20% Vs 10%) and LVEDD at follow-up. The authors state that as a maker of electrical remodelling, it might be a better idea to look at narrowing of native QRS rather than that seeing paced QRSd, whose duration may vary. However it may be worth recording whether, and in how many, the QRS duration pre-implant may also change due to similar factors. This will of course confound any kind of measurements of Δnative-QRSd.

Fragmented QRS (fQRS) in the ECG implies presence of scar as well as electrical dyssynchrony and even forms part of the

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strict LBBB criteria [1]. Two recent studies aimed to investigate the relation of resolution of fQRS with favourable response post CRT. In the study by Wang et al. [4] in 75 CRT patients, responders had decreased fQRS post CRT while non-responders had increased fQRS post CRT. Reduction in fQRS in ≥1 lead had high specificity (95%) but low sensitivity (19%) for favourable CRT response. In the study by Celikyurt [5] et al. among 67 patients with LBBB and fQRS who underwent CRT, number of leads with fQRS decreased significantly among responders (4.4 pre to 1.7 post CRT) but did not change among non-responders. In this study, resolution of fQRS was the only predictor of response to CRT. While resolution of fQRS is expected logically in those with electrical and anatomic remodelling, it is not examined as a routine in post-implantation follow-up. These studies suggest that besides looking at QRSd, we need to also document response of CRT on fQRS, as both are independent.

Electrocardiographic recognition of biventricular capture and location of ventricular leads

There has been substantial research on electrocardiographic recognition of effective left ventricular capture during biventricular pacing. Many algorithms have been published in the last 15 years, but have proven less than ideal. Increasingly different placement of the RV lead in non-apical position and LV lead beyond the postero-lateral area has challenged these conventional algorithms. The ECG recognition of biventricular pacing is important to recognize LV capture when access to programming device is not possible as well as for teaching. One of the hallmarks of LV pacing on the ECG, taught for many years, has been the presence of a dominant R in lead V1 and an initial q in lead I. However several studies have shown that dominant R can be present in isolated RV pacing, and that it may be absent in case of non-apical RV pacing. Barold [6] has summarized the data regarding the utility as well as the controversy regarding lead V1 in a recent editorial. Besides the lead related issues as mentioned above, absence of R wave in lead V1 despite biventricular pacing can happen due to regional exit blocks (with or without latency) around the lead target area as well as generalized conduction disturbances and placement of the lead in middle cardiac vein or anterior veins. Thus it is clear that mere placement of a lead in desired area or presence of a dominant R in V1 may not be enough to ensure optimal fusion of biventricular pacing.

Jastrzebski et al. [7] recently published a universal algorithm for recognition of biventricular capture among a large sample of 443 CRT patients. Keeping in mind increasing non-apical RV pacing, biventricular capture was diagnosed if the QRS in lead I was predominantly negative and either V1 QRS was predominantly positive or V6 QRS was of negative onset and predominantly negative (step 1), or if QRS complex duration was <160 ms (step 2). All other ECGs were classified as loss of LV capture. The ECGs for algorithm construction (n = 350) and validation (n = 439) were separate. The algorithm demonstrated good sensitivity and specificity (both above 90%) and accuracy (93%) independent of either RV or LV lead position. Similarly Cao et al. [8] also described a similar method combining predominantly positive forces in V1 with predominant or initial negative forces in lead I for diagnosis of LV capture. They also tested another algorithm confirming this diagnosis by shifts in QRS axis during pacing (rightward with LV capture). Both the algorithms had reasonable accuracy and improved efficacy over previous algorithms. However the axis shift method appears cumbersome.

On the other hand a small but meticulously carried out single centre study by Sommer et al. [9] sought to confirm the right and left ventricular lead locations as determined by common algorithms by paced QRS characteristics, in comparison to lead position seen on a cardiac CT. Notably these algorithms have usually relied on fluoroscopic locations for confirmation, which themselves may be fallacious according to a previous study by the authors [10]. In this study 97 patients were studied with stable lead position after 6 months of implantation with paced LV only and RV only lead rhythms and a cardiac CT done as part of an ongoing study. During LV forced pacing, while broadly anterolateral Vs posterolateral and basal Vs apical position had different QRS morphologies, these had average sensitivity and specificity only with different morphologies seen often while pacing from identical LV myocardial segments. An interaction was found with aetiology of heart failure, entirely plausible as a large scar in free wall of LV may cause unexpected activation pattern and axis changes. There was no correlation of forced RV paced rhythms with the RV lead position. According to authors no paced QRS characteristic can reliably confirm specific LV and RV pacing sites in CRT and this makes a strong case for imaging guided lead positioning. Interestingly while only 60% patents had an inferolateral lead position, the LVEF of the overall group improved by a mean of 13% which underscores the complex interplay of factors that determine CRT outcome.

Conflict of interest

No conflict of interest declared for this manuscript.

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