Left ventricular endocardial pacing for the critically ill

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WHAT'S NEW IN INTENSIVE CARE

Left ventricular endocardial pacing for the critically ill

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Introduction

Two decades ago cardiac resynchronization therapy (CRT) developed as a modality to reduce morbidity and mortality in patients with left ventricular (LV) dysfunction and a wide QRS complex (> 120 ms) [1]. Twenty years earlier Gibson et al. had provided evidence of higher contractile force during biventricular as compared to right ventricular (RV) pacing in six patients on the critical care unit immediately after replacement of the aortic valve with a Starr-Edwards prosthesis [2].

Haemodynamic effects and pathophysiological benefits of LV endocardial pacing

Patients with a wide QRS complex, especially those with left bundle branch block (LBBB), and impaired LV pump function receive significant acute haemodynamic benefit with CRT using pacing at the RV endocardium and the LV epicardium via the coronary sinus [1]. Beneficial effects of CRT include increases in acute contractility (measured by LV dP/dt_{max}), stroke work and cardiac output without the detrimental effect on myocardial oxygen demand seen with inotropes [3, 4]. Such effects may also be useful in critically ill patients. Evidence suggests that LV endocardial stimulation can provide a further improvement in acute haemodynamic response (AHR) over LV epicardial stimulation [5–7]. LV endocardial pacing may also provide access to optimal pacing sites in the LV. The superior AHR by LV endocardial pacing has been demonstrated in animal studies [5], computer modelling [6] and human studies [7]. Strik et al. found that in canine LBBB models LV endocardial stimulation increased LV dP/dt_{max} over conventional epicardial stimulation along with reduced electrical activation times as measured by contact mapping [5] (see Fig. 1). The exact mechanisms underlying the decreases in activation times for LV endocardial stimulation have not been fully elucidated but may include shorter activation path lengths for endocardial stimulation allowing earlier activation in remote regions and earlier activation of fast-conducting endocardial tissue, which has a higher conduction velocity (CV) than epicardial tissue [5]. Computer modelling studies support this showing that LV endocardial stimulation creates a more physiological (i.e. from endocardium to epicardium) and more synchronous electrical activation resulting in superior LV contractility compared to epicardial CRT [6]. Human studies in patients with chronic heart failure have supported these experimental findings especially in patients with ischaemic heart disease where LV endocardial pacing may improve haemodynamics by avoiding pacing within LV scar and targeting areas of late electrical activation [7].

Currently, there are various possibilities to deliver LV endocardial pacing including the use of a bipolar trans-septal lead [8], endocardial LV septal via bipolar lead [9], wirelessly [10] or using a deeply inserted temporary pacing wire at the time of cardiac surgery. A disadvantage of trans-septal LV endocardial CRT using a standard bipolar lead is that the currently available tools are limited, may alter mitral valve function and long-term anticoagulation is required. Therefore, clinical studies are limited to patients who either cannot receive standard CRT or who have not responded to it [8]. The industry-sponsored, non-controlled ALSYNC study also demonstrated that there are a non-negligible number of potential complications with chronic LV endocardial CRT, such as stroke, transient ischaemic attacks and major haemorrhage due to the need for effective anticoagulation [8]. However, application of LV endocardial CRT using trans-septal and transmitral lead placement is

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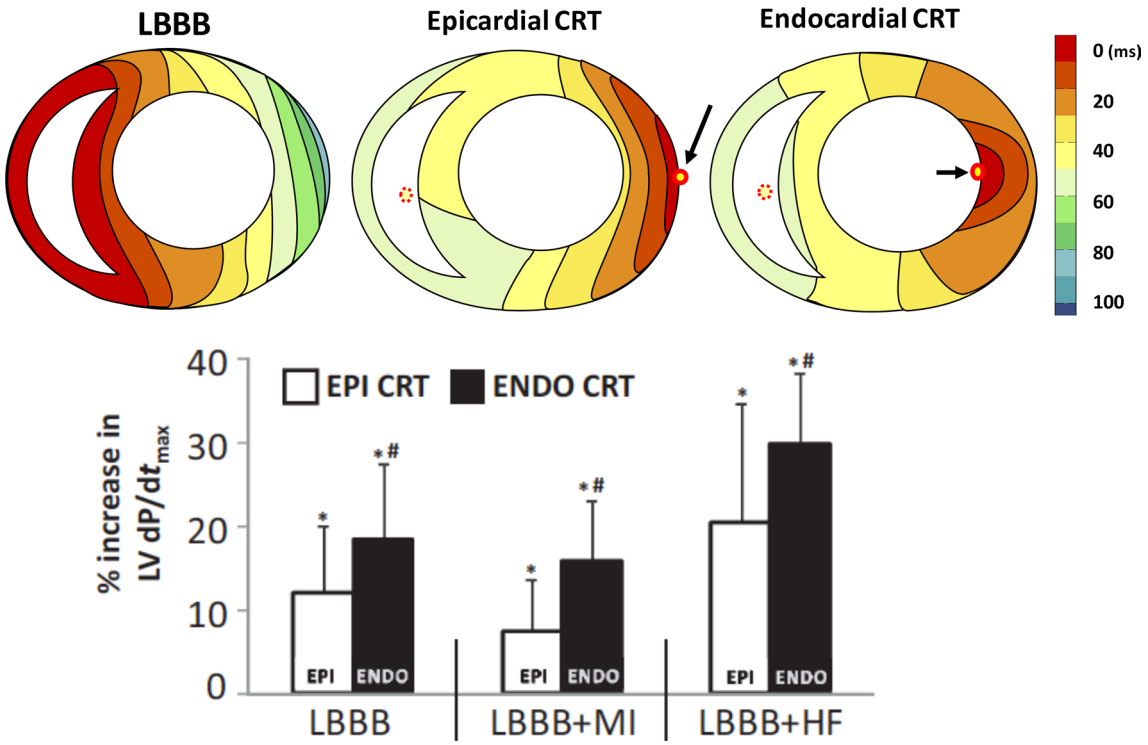

Fig. 1 Electrical activation during baseline LBBB, epicardial CRT and endocardial CRT, obtained by electrode band and multi-electrode array mapping in the dog model. Reproduced with permission from Ref. [5]. The red/orange circles denote the RV apical and LV pacing electrode. Lower panel shows changes in acute haemodynamic response with endocardial and epicardial pacing in the presence of LBBB alone, LBBB and infarction (MI) and LBBB and heart failure (HF). *Significantly different from baseline, #Significant from epicardial pacing

unpractical in the emergency setting as the technique is technically demanding, requiring long procedures involving fluoroscopy and the inherent risks and complications of left-sided catheterization [8]. Instead, patients undergoing open-heart surgery could be implanted with a temporary wire that is placed deeper in the LV wall (this would require redesign of the current temporary pacing technology). Finally, new tools for long-term use of LV endocardial pacing using a novel wireless technology for transmitting pacing energy only require a short period of oral antiplatelet therapy [10].

Potential use of LV endocardial stimulation in critically ill patients

Several reasons to use pacing in the critically ill have been proposed. The first application of pacing is treatment of bradycardia, commonly using external pacemakers. The standard site of the ventricular electrode is the RV which like LBBB creates electrical and mechanical dyssynchrony that often worsen haemodynamics [11]. Secondly, biventricular pacing may be used to prevent ventricular desynchronization or to restore synchrony. The BLOCK-HF study demonstrated the benefit of biventricular pacing compared to RV pacing, with concurrent improvement of pump function and outcome in the chronic setting [12]. In keeping with this, BiV pacing can improve haemodynamics and reduce inotropic requirements in the setting of recovery from (open-heart) surgery [13]. This reduction in inotrope use may reduce myocardial oxygen demand [3] while resynchronization itself has also been shown to reduce myocardial oxygen consumption per unit of mechanical work [4]. Control of atrioventricular contraction interval by programming atrioventricular delay may also be important in patients with a prolonged PR interval, where ventricular filling may be improved. In the setting of chronic heart failure, biventricular pacing may be harmful when the QRS complex is narrow (< 120 ms) [14]. However studies in the emergency setting show potential benefit with biventricular pacing in patients with a narrow QRS complex and mechanical intraventricular dyssynchrony [15]. Moreover in the porcine model acutely RV-overloaded hearts benefit from RV pre-excitation, whereas acute LV overload requires LV pre-excitation suggesting a further potential mechanism of benefit of biventricular pacing (with properly programmed AV and/or VV intervals) by recruitment of the non-overloaded ventricle to support the overloaded one through mechanical interaction between the ventricles [16].

A relevant question is whether there are scenarios where LV endocardial pacing may be of additional benefit in critically ill patients. Currently the standard way to stimulate the LV is via a pacing lead either placed transvenously in a coronary vein or using a temporary epicardial wire post-surgery. Firstly, it must be emphasized that LV endocardial pacing in the setting of the critically ill patient is speculative, with very little data to support its use. As outlined above, it would make physiological sense to move from LV epicardial to LV endocardial pacing. Moreover, some of the problems that apply to the chronic patient may not be relevant in the emergency setting because patients are often already anticoagulated.

Conclusion

LV endocardial pacing is pathophysiologically plausible, but its feasibility and benefit in critically ill patients are yet to be proven. The complexity of current LV endocardial pacing lead implantation hampers application in the emergency setting. Post-surgical conditions, however, may offer the opportunity to implant newly designed LV endocardial leads that can subsequently be used for longer-term resynchronization. In any case the potential haemodynamic benefits of LV endocardial pacing have to be balanced against the potential for harm by delivering stimulation within the LV cavity.

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Compliance with ethical standards

Conflicts of interest
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