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Intracardiac impedance to track cardiac volume status during cardiac resynchronization therapy – The quest for a heart failure sensor

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1. Introduction

Cardiac resynchronization therapy (CRT) reduces heart failure (HF) hospitalizations, improves patient wellbeing and survival [1]. However, some patients remain vulnerable to recurrent HF, even when receiving best electrical optimization [2]. Among these, outcomes remain poor and health care expenditures are increased [3–5]. In practice, this group of patients receive little additional therapy. There is a need to identify measures for the prevention of repeated HF episodes.

Remote monitoring may offer an opportunity. We know that intracardiac pressures may change 2–3 weeks before clinical presentation [6]. This interval represents an opportunity for physicians to intervene and prevent a hospitalization. This requires the ability to track a signal linked to cardiac hemodynamics and implement pre-emptive therapy. Such a parameter exists. Thus, among a group of CRT recipients with recurrent HF, action taken in response to remotely assessed pulmonary artery pressures reduced HF hospitalizations and improved QoL compared to traditional clinical management [7]. However, direct pulmonary artery pressure monitoring requires implant of an additional device solely for monitoring. The question arises: is it possible to access a similarly actionable signal from the CRT unit only? Continuous monitoring from implanted devices generates a wealth of diagnostic data, and these may contain such identifiers of impending clinical deterioration. However, despite multiple attempts, results to date have been indifferent [8].

Thoracic impedance was proposed as a hemodynamic surrogate, based on the hypothesis that impedance measured between pulse generator and RV lead may reflect tissue (ie lung) hydration and therefore heart failure status. Despite extensive testing, results have been disappointing. Metaanalysis indicated no difference in HF -related admissions rate, all-cause mortality or combined

admission rate and all-cause mortality between the device monitored and the control group [9]. Lack of specificity is a problem, generating the risk that inappropriate therapy for false positive notifications (eg respiratory infections) may cause patient harm [10,11].

The current investigators assessed intracardiac impedance (ICI) and its correlation with echocardiographic estimates of cardiac output [12]. This is a novel metric and distinct to thoracic impedance as described above. Possibly, changes in impedance across the heart (without intervening lung tissue) reflect cardiac performance more accurately than thoracic impedance. In ICI, voltage is sampled by the LV electrode in response to current injected between RV lead tip and coil to derive end-diastolic and end-systolic impedance. The difference represents stroke impedance. The current has to be carefully titrate to prevent inadvertent myocardial capture. The working impedance is in the milli-ohm range (much lower than thoracic impedance) and more vulnerable to respiratory influence and noise. Therefore sampling is has to occur over longer periods ie several minutes. Some prior intracardiac hemodynamic studies showed that stroke volume changes associated with changing heart rates correlated with ICI [13].

Here, the investigators present results of an acute validation study occurring 2 months after device implant. The CRT population was typical excepting the high (70%) incidence of mitral regurgitation. The value of ICI was assessed by correlation with stroke volume measured by echocardiographic aortic VTI during overdrive pacing at different heart rates. The strengths of the trial are multi-center design and use of an echocardiographic core lab. The observation of 0.80 correlation between SZ and aortic VTI indicates a positive study result.

Several limitations have to be acknowledged. ICI derivation depended on bipolar leads with a specific inter-electrode distance, in a designated LV position, whereas quadripolar leads are standard of care. Whether ICI and its performance are affected by lead maturation occurring over years is unstated, leading to questions about the reliability of chronic measurements. The authors had to change their pre-specified measure of end-diastolic impedance to the minimum impedance recorded in an 80 ms end-diastolic window. This appears valid given prior data presented. Importantly, results were obtained in stationary supine patients, so the impact of upright posture, exercise and increased respiratory rates during real-world ambulatory activity are unknown. A significant limitation is that there was no test of clinical HF- stroke volume changes were created by altering paced rates. Enrollment criteria excluded patients with decompensated HF and did not differentiate responders vs non-responders to CRT therapy, although these analyses may have been instructive. Questions remain as to how ICI is affected

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by the balance of RV failure vs LV failure or “forward” vs “backward” failure. The degree of advance notice of HF decompensation provided by ICI compared to eg PA pressure monitoring among CRT patients needs to be established.

In summary, the authors are to be commended for this investigation of the acute performance of a novel potential HF sensor embedded in implantable CRT units. There is a huge need for an alert notification enabling early detection HF among CRT patients followed by automatic continuous remote monitoring [14,15]. Such a sensor also may enable a hemodynamically-based (as opposed to electrogram-based [2,16] CRT dynamic optimization algorithm. We look forward to further work to establish the efficacy of ICI these purposes.

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