Cardiac CZT-SPECT: More than left ventricular imaging

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The concept of equilibrium radionuclide nuclear angiography (ERNA) has come a long way since it was first introduced in the late 1970s as the gated equilibrium blood-pool time activity method where left ventricular ejection fraction (LVEF) could be determined from planar images and soon after also right ventricular ejection fraction (RVEF) from first pass imaging^{1,2} being a new alternative to cardiac catheterization with contrast ventriculography. Non-invasive and radiation free methods for assessment of cardiac function has since then emerged in the shape of MRI, bioelectric impedance, indicator dilution technique and echocardiography along with further development of radioactive tracer techniques such as myocardial perfusion imaging and cardiac CT as a radiographic alternative. This multitude of available methods for determination of cardiac function has inevitably increased the demand for comparative studies in order to evaluate which methods best serve a given patient population in terms of information provided along with accuracy, reproducibility, availability, cost, risk and practicability. One of the emerging modalities is Cadmium Zinc Telluride gated SPECT equilibrium radionuclide angiography (CZT-ERNA).^{3,4}

In this context the study in this issue of Journal of Nuclear Cardiology by Apert et al.⁵ fills in a part of the gap of lacking information on this subject with their

examination of right ventricular volumes and ejection fraction in patients with cardiomyopathy. Apert and colleagues are among the first to report on the reproducibility and accuracy of CZT-ERNA compared to cardiac magnetic resonance imaging (CMR) in patients with cardiomyopathy. They examined twenty-one patients with cardiomyopathy (both ischemic and non-ischemic) who were referred for the evaluation of possible later implantation of left ventricular assist devices. The right ventricle is of importance in this setting, as it is left non-assisted and right ventricular failure can be seen post implantation. They found that CZT-ERNA provides accurate and reproducible results regarding the right ventricle when compared to CMR even in a population with reduced LVEF—yielding yet a promising indication for cardiac CZT scans. Especially the fact that the right ventricular volumes are comparable to those obtained from CMR, is important as right ventricular function is more difficult to assess due to its thin myocardium, irregular shape and difficulties defining the valvular plane of the pulmonary artery as compared to the left ventricle.

There are limitations specifically related to the CZT technique itself, also denoted in the study by Apert and colleagues. A total of 7 patients could not be evaluated either due to irregular heart rhythm (3 patients) or due to centering problems which made RV evaluation impossible (4 patients). Irregular heart rhythm is a potential confounder for most non-invasive techniques when evaluating right or left ventricular function—including CMR. Nonetheless, ERNA recorded in list mode enables re-binning of the acquisition for analysis of user selected R-R intervals in cases with irregular heart rhythm,^{6,7} which is not available for CMR and echocardiography to the same extent. With the CZT camera at hand for Apert et al. there is an automated function for “finding the heart” prior to acquisition, which works for myocardial perfusion imaging only. When it comes to ERNA this is

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an operator-dependent procedure potentially reducing practicability of ERNA.

Upon introduction of new techniques, the practicability of the method is always of importance—thus for the current ERNA technique to be generally accepted and taken up for general use—a four out of twenty-five patients = 16% failure rate due to centering problems is perhaps too high in a clinical setting. However, in a far larger study with routine monitoring of LVEF with CZT-ERNA the technique has proven practicable in 98% of referrals. Of the remaining 2% of referrals ERNA could be achieved with either planar or Sodium Iodide (NaI)-SPECT in the majority of cases. Only 0.5% of all referrals required estimation of cardiac function with other modalities.⁸ Most cases where CZT-ERNA was not possible were due the inability of some patients to raise their left arm above their head (1%) and large thoracic circumference (0.5%). Another drawback with the study by Apert et al. is the relative low number of included patients, which does not allow for stratification into bins of near-normal to very-low RVEF, to test whether the performance of CZT-ERNA compared to CMR is stable at very-low RVEF as well. Nonetheless, the results are still quite convincing for the patient group as a whole.

CZT cameras for ERNA also have other advantages than measuring right ventricular function compared to traditional gamma cameras. It is possible to reduce both examination time⁹—thus increasing throughput and availability—and reduce administered tracer dose especially if using individually adapted dosage.¹⁰ The latter is particularly important for patients requiring continuous cardiac monitoring while undergoing potentially cardiotoxic treatment. The same holds true for patients in the need for cardiac function monitoring for other indications where echocardiography or CMR are either unavailable or unsuitable. Moreover the reduced patient dose will inevitably lead to reduced dose to the staff and even reduced cost as both tracer and radioisotope consumption decline.

Another feature with the CZT-ERNA technique that has been demonstrated by others and once again confirmed by Apert et al in the study in this issue is the low variability of cardiac measurements.¹¹ This high reproducibility extends to other variables than RVEF/LVEF such as peak emptying and filling rates (PER and PFR, respectively) for both left and right ventricles as well as time to peak filling rate (TTPFR). Moreover reference ERNA data for CZT-SPECT in chemotherapy naïve cancer patients have been published for both LVEF and RVEF along with ventricular volumes, PER, PFR and TTPFR.^{4,12} Thus the diagnostic certainty is increased when evaluating cardiac variables and changes during a course of potentially cardiotoxic treatment or other

interventions. Apert et al also indicated, that manual intervention were more often required and took longer for CMR images than for CZT studies, were the automated QBS software was a clear advantage for the latter. From a research point of view, a study using tests with such practicability, reproducibility and low variability will inevitably require fewer included patients than studies using tests with poorer performance and subsequently shorter study duration and lower costs. Nonetheless, it is still mandatory to evaluate in detail for each cardiotoxic regime or other monitoring indication to what degree the better practicability and other qualities of CZT-ERNA outweighs the potential risks of using a radioactive tracer for routine continuous monitoring of cardiac function.

Even though CZT-SPECT cameras are as yet considerably more expensive than their NaI counterparts they do provide improved imaging quality, faster acquisition and lower radioactive dose to both patients and staff. Moreover, they provide a practicability beyond what can be achieved with both MRI and echocardiography for both myocardial perfusion imaging and ERNA although backup NaI gamma camera systems may still be required for some patients.

All in all, the study by Apert and colleagues add to the cumulating evidence that CZT-ERNA is a reliable method for the evaluation of both right and left ventricular volumes and function—also in the setting of cardiomyopathy. This further underlines the many facets and possible indications for cardiac CZT-SPECT, not only for RVEF/LVEF assessment using ERNA SPECT, but also for other well-established indications such as myocardial perfusion imaging¹³ and newer not yet fully established indications such as amyloidosis¹⁴ and the possibility for dual isotope studies, i.e., combined WBC scan/perfusion studies.¹⁵

Declarations

Disclosure

The authors have no conflict of interest to declare.

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