A further step towards getting cardiac respiratory motion under control

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Single-photon emission computed tomography myocardial perfusion imaging (SPECT-MPI) is a widely available and well-established non-invasive modality for the evaluation of ischemic coronary artery disease.^{1,2} Although technological advances have enabled implementation of other functional cardiovascular imaging modalities into clinical practice, SPECT-MPI promises to continuously hold a pivotal role into the diagnostic assessment of the cardiovascular patient whereby the ongoing departure from the conventional orbiting sodium iodide (NaI) detector-based SPECT cameras and introduction of cadmium-zinc-telluride (CZT) solid-state detector-based gamma cameras has certainly played a crucial role. The superior sensitivity of CZT detectors over traditional NaI detectors and sophisticated newest generation iterative reconstruction algorithms in combination with instantaneous acquisition of tomographic data without the need of detector rotation provides superior count rate, reduction of image noise and significant improvement in spatial resolution and overall superior image quality while enabling decreased acquisition time and/or radiotracer activity and intermittent scanning.^{3–5} However, on a per-patient basis, the diagnostic performance of the modern-era cameras has not yet been proven to be superior to conventional SPECT gamma cameras.⁶ Moreover, the cost of CZT camera systems remains a controversial topic, alongside several other inherent limitations.⁷ Among the latter,

detection and correction of patient and respiratory motion constitute a field of ongoing research. While reduced acquisition time enabled by CZT technology may substantially reduce the prevalence of artifacts due to patient motion, respiratory motion remains a more delicate source of artifacts as it is a quite complex three-dimensional movement occurring predominantly in—but not limited to—the craniocaudal axis, potentially causing artifacts in the inferior wall. While several approaches have been proposed for cardiac respiratory motion detection, including external respiratory sensors or infrared cameras,^{8–10} motion correction remained challenging for SPECT-MPI with conventional gamma cameras using rotating detectors in a step-and-shoot mode. By contrast, the stationary design of a CZT system with data acquisition in list mode has paved the way for a more elegant solution, namely, through purely data-driven cardiac respiratory motion detection and correction.^{11–13} To date, however, quantification of a potentially beneficial impact of such algorithms on SPECT-MPI is lacking.

In the current issue of the Journal of Nuclear Cardiology, Daou *et al.* assess the impact of such purely data-driven cardiac respiratory motion correction on the extent and severity of (apparent) myocardial perfusion defects. After demonstrating applicability and feasibility of a motion detection and correction software algorithm (REGAT),¹³ the authors now translate their preliminary findings into clinical routine by examining its practical implementation in a small sample of patients: In 25 patients undergoing 1-day stress/rest ^{99m}Tc-tetrofosmin SPECT-MPI acquired on a CZT camera, the severity and extent of myocardial perfusion defects were compared with and without respiratory motion correction on a visual as well as on a semi-quantitative basis in a total of 49 combined stress and rest studies. On visual assessment, correction for respiratory motion had an impact on the extent and/or severity of a myocardial perfusion defect in 7 of 49 studies (14%), leading to a

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decrease in 6 out of these 7 studies with the correction expectedly, in particular, affecting the inferior wall. Importantly, the magnitude of cardiac respiratory motion was related to the effect of correction, as 7 of 27 studies (26%) and 3 of 5 studies (60%) with respiratory motion of >10 and >15 mm, respectively, were impacted by respiratory motion correction. Of note, gated SPECT analysis was not performed at this level, as ECG gating was not implemented, therefore not allowing for evaluation of left ventricular volumes and ejection fraction of the respiratory motion-corrected datasets. Furthermore, the REGAT software algorithm currently uses a rigid realignment of the left ventricle, and it remains elusive how a more advanced non-rigid realignment may impact motion detection and correction.

At first glance, and as the authors mention themselves, the impact of respiratory motion correction may seem moderate at best in view of only 14% of the studies being impacted. However, this number should be put into the proper perspective by comparing the impact of attenuation correction (AC) with computed tomography (CT) on SPECT-MPI, where a significant diagnostic modification was demonstrated in about 20% of abnormal SPECT studies when AC was applied.¹⁴ Furthermore, recent data have shown a beneficial effect of respiratory-phase matching between SPECT and CT for AC on image quality and an increase in the frequency of normal scans compared to using conventional free-breathing SPECT with CT for AC acquired at breath-hold.¹⁵ While it has yet to be elucidated whether a purely data-driven respiratory motion correction of SPECT may confer a similar benefit on CT attenuation corrected SPECT, it is not unlikely that concomitant correction of attenuation and respiratory motion may even be synergistic, i.e., more powerful than the sum of its parts.

Importantly, in the current study, respiratory motion correction not only increased the normalcy rate but also led to an increase of defect extent/severity in two studies. Due to a lack of a functional standard of reference in the present study, it is unclear whether this represents unmasking of true perfusion defects or rather an introduction of novel artifacts. Do we gain sensitivity or lose specificity? Whichever may be the case, future studies are needed to improve our understanding on how to handle and interpret these changes in clinical routine, similarly to CT AC which is well known to introduce artifacts or overcorrect findings.

The introduction of CZT cameras has been heralded as a major leap forward in SPECT hardware technology development. However, several improvements remain essential for this novel technology to deliver the anticipated additional benefit in clinical routine, and

respiratory motion detection and correction should be counted among them.^{7,16} Against this background, the authors need to be praised for their research as it represents an illustrative example of transforming theory into a prototype, proving its feasibility and applicability, and finally demonstrating its impact in a real-world clinical setting. However, it goes without saying that the books are far from closed as it remains yet to be elucidated whether data-driven cardiac respiratory motion detection and correction may eventually confer a significant beneficial impact on the diagnostic performance of CZT SPECT imaging.

Disclosure

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