EDITORIAL

Breathless or breathtaking: Respiratory motion correction

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Please do not move, take a deep breath, and hold it for the next minutes. This would result in an absolute respiratory and patient motion-free myocardial perfusion imaging (MPI) SPECT acquisition—or in a breathless patient.

Thanks to substantial refinements over the past decade MPI SPECT has evolved remarkably and represents a well-established method to assess diagnosis and prognosis in patients with coronary artery disease. However, artificial defects, loss of resolution, image blurring, or even noninterpretable datasets have been described due to patient motion (PM) and respiratory motion (RM).[1–3] Although motion has been recognized as a potential source of error, the optimal approach to reduce the occurrence and extent of such artifacts has yet to be found.

A revolutionary milestone in the era of SPECT MPI, with the introduction of latest generation cadmium-zinc-telluride (CZT) semiconductor detectors technology and a heart-focused design with optimized image reconstruction software,[4] has not only resulted in improved count sensitivity and spatial resolution, but has also paved the way for innovative protocols with drastically reduced image acquisition time[5] or lower radiation dose.[6–8] This has stimulated research on promising methods for the elimination of motion either prospectively or retrospectively. Motion tracking software[9–11] or prospective respiratory triggering during inspiration breath-hold[12–14] has been reported to eliminate motion. Although the clinical value of the latter has been repeatedly demonstrated,[12–14] such an approach inevitably complicates and prolongs acquisition protocols. Therefore, implementation of retrospective respiratory gating might represent a more adequate strategy for controlling RM in daily clinical routine and has recently been reassured by studies that validated different motion detection and correction algorithms for CZT cameras successfully.[9–11] Notwithstanding the accuracy and reliability of these algorithms, their impact on diagnostic accuracy is yet unclear.

In the current issue of the Journal of Nuclear Cardiology, van Dijk et al.[19] investigated motion of patients undergoing CZT MPI SPECT in order to determine the value of an automatic motion detection and correction software (MDC for Alcyone, GE Healthcare). This commercially available software retrospectively bins list-mode data from 5 pinhole projections and reconstructs five dynamic images from 5 central pinholes. Five virtual lines are drawn through the intersection of the myocardium center of mass and each of the five pinholes. The point with the smallest distance from these lines is calculated (in the x, y and z dimension) for each bin. Finally, the software tracks motion by comparing all points and generates a system matrix that incorporates the identified motion. In order to validate this software, the authors performed a phantom test that demonstrated an accurate detection of RM > 2 mm and PM > 1 mm. In their retrospective study, 83 consecutive patients with intermediate anatomical coronary lesions who underwent stress/rest ^{99m}Tc-tetrofosmin SPECT MPI were included. Remarkably, FFR measurement by invasive coronary angiography was performed in all patients. A fixed scan time of 8 min for stress acquisition was used, and data were acquired in list-mode. Attenuation correction was not performed in this study. For RM and PM detection, emission data were reformatted into 1 s and 20 s time bins. Nonmotion-corrected scans were compared with corrected scans by qualitative (visual) and semiquantitative (total perfusion deficit [TPD];

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Table 1. Motion detection and correction in CZT cameras

MD-algorithm	Patients	Tracer	Scan time	Bins/frames	Motion cranio-caudal	Motion lateral	Motion ventral-dorsal	Relevant motion from phantom validation	Reference
MAPEM	552	^{201}Thallium	3 min	0.5 s	10.5 mm (pharm) 12.3 mm (treadmill)	2.6 mm (pharm) 2.9 mm (treadmill)	2.3 mm (pharm) 2.6 mm (treadmill)	≥15 mm	Ko et al.[9]
ShIRT	40	^{99m}Tc-tetrofosmin	6 min	30 s	0-4 mm: 62% of pts 4-8 mm: 35% of pts ≥8 mm: 4% of pts	≥8 mm: 0% of pts	≥8 mm: 0% of pts	≥10 mm	Redgate et al.[10]
REGAT	18	^{99m}Tc-tetrofosmin	5 min	0.5 s	9.7 mm (stress) 10.7 mm (rest)	1.4 mm (stress) 1.7 mm (rest)	1.4 mm (stress) 2.2 mm (rest)		Daou et al.[11]
MDC	83	^{99m}Tc-tetrofosmin	8 min	1 s 20 s	2.5 mm (RM) 1.2 mm (PM)	0.9 mm (PM)	1.0 mm (PM)		van Dijk et al.[19]

MD motion detection, *REGAT* respiratory gating software, *ShIRT* Sheffield image registration toolkit, *pharm* pharmacological stress, *RM* respiratory motion, *PM* patient motion, *pts* Patients segmental uptake) parameters. If diagnostic outcome changed due to motion correction, the results were compared to FFR results.

In their study, the mean RM was 2.5 ± 0.4 mm and the maximum PM was 2.4 ± 0.8 mm, 2.8 ± 0.9 mm, and 3.4 ± 1.5 mm in the lateral, ventral–dorsal and cranial–caudal direction, respectively. Of note, the mean RM decreased during the scan, especially during the first 2 min. Changes regarding the visual interpretation occurred in nine patients (11%) after applying the RM correction algorithm. However, based on FFR as standard of reference, this resulted in deterioration of the diagnostic outcome of five of these nine patients (6% of the total study population). A TPD change ≥7% occurred in two patients (3%) after RM correction was applied and resulted in one patient having improvement and another having deterioration based on FFR. A segmental uptake change ≥5% occurred in 57 patients (69%) and resulted in an improvement according to FFR in 30 patients, but resulted in deterioration of 15 patients and remained unknown in 12 patients. The patient motion correction did not change diagnostic outcomes in any of the patients based on SPECT interpretation or TPD. However, based on ≥5% segmental change, the segmental uptake values were corrected in seven patients. Finally, the amount of motion correction and the mean RM or PM did not correlate.

This study adds an important piece to the puzzle of detecting and correcting motion in MPI SPECT. With the introduction of CZT cameras, the application of motion detection and correction algorithms has lately regained widespread interest.[10,11] The authors should be congratulated for this comprehensive study investigating a commercially available software to automatically detect and correct motion. The study is well conducted, and the results are clearly presented. One of the strengths of the study is the use of invasive FFR as the standard of reference. Nevertheless, it is arguable whether invasive FFR is the ideal standard of reference since concordance between SPECT and invasive FFR has previously been shown to be modest,[15,16] even in the same study population.[17] Moreover, the authors' effort to validate the software tool with a basic phantom test adds fundamental background information on its accuracy. The finding that insufficient count statistics might lead to a deterioration of image quality is problematic—particularly in view of the projected steps to decrease radiation exposure through lowering isotope doses and prolonging acquisition times.[6] As the authors state themselves, the motion detected by MDC in this study, especially RM, was substantially smaller than reported in previous studies.[9–11] In consideration of the mean RM and PM of 2.5 mm and 1.2 mm, the authors conclude that correction of this small motion did not appear to improve the diagnostic outcomes, and hence the value of applying motion correction seems limited in MPI CZT SPECT. Based on visual interpretation, this seems to be entirely true in this study population as the SPECT interpretation, after applying the motion correction algorithm, changed in 11% of patients of whom 44% resulted in an improvement and 56% resulted in deterioration. However, a segmental uptake change ≥ 5% occurred in 69% of the study population. Furthermore, in addition to the above-mentioned comment on FFR as the standard of reference, this needs to be put in the perspective of recently published work on that topic (Table 1). The scan duration seems to play an important role regarding motion. While scan duration lasted between 3 and 6 min in the previously reported studies,[9–11] it was 8 min in this study. The higher detected motion in previous studies seems in line with the important finding of van Dijk et al.[19] that RM decreased significantly during the scan, especially in the first 2 min (e.g., motion was highest during the first 2 min). This might suggest that shorter scan protocols—which have become feasible due to CZT detectors—might be more susceptible for motion as the first minutes of excessive movement have a higher relative impact, and therefore motion detection and correction algorithms may play an even more important role in short acquisition protocols. Of course, prolonged scan durations as used in conventional SPECT will again increase the likelihood of motion artifacts.[18] Explanations, such as longer time bins and higher myocardial count rates, have been discussed in the study of van Dijk et al.[19] Additionally, the type of stress (pharmacological vs treadmill) seems to play a role as Ko et al. have reported a significant higher motion along the cranio–caudal axis in patients who have undergone SPECT MPI after treadmill stress.[9]

As emphasized by the authors, comfortable environment and sufficient patient information are mandatory principles to reduce motion, but it remains questionable that this will be sufficient in all circumstances. Whether latest technologies for motion detection and correction are a breathtaking breakthrough or whether breathless patients will be the future still seems to require further investigations.

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