EDITORIAL

Advances in dual respiratory and ECG-gated SPECT imaging

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In the current issue of Journal of Nuclear Cardiology, Kortelainen et al report that a new method of acquiring dual respiratory and ECG-gated SPECT myocardial perfusion data reduces artifacts due to respiratory motion while leaving asynchrony measurements derived from the data unaltered.[1] As the improvements reported were modest and only observed in a subset of subjects, a relevant question to ask is whether the additional equipment needed and patient preparation logistics would significantly improve patient outcomes. Is pulmonary motion actually a significant problem in nuclear cardiology imaging, requiring a solution?

There is a long history of exploring data acquisition and processing methods to detect and compensate for the repositioning of organ systems due to breathing in scintigraphic imaging, notably for PET studies to improve the detection of tumors involved in lung cancer.[2] In the realm of cardiac imaging, it was recognized as early as 1989 that changes in breathing patterns over time could degrade Tl-201 SPECT myocardial image quality if data acquisition was initiated too early following treadmill exercise,[3] the remedy for which was to delay the start of imaging. Even with this change in technique, myocardial motion due to normal breathing patterns has been shown to degrade image quality and affect quantified myocardial perfusion.[4] In 2009, several papers appeared documenting the effect of respiratory motion on SPECT perfusion assessment and proposing solutions.[5-7] Now, in conjunction with protocols involving imaging the heart while it is in a stressed state, corrections for breathing motion have been shown to improve accuracy not only of relative myocardial perfusion evaluation but also of absolute myocardial blood flow quantitative measurements as derived from Rb-82 PET data.[8] There are advantages to ECG-gating both rest and stress PET data, and newer rest/stress SPECT protocols are being implemented such that the heart is in a genuinely different physiologic state during stress SPECT acquisition,[9] raising the prospect that it may become important to detect and correct for changes in breathing patterns induced by stress.

Initially, the main focus of Tl-201 and Tc-99m-sestamibi SPECT imaging was relative myocardial perfusion assessment, but with ECG-gating, additional parameters can be measured as well, including LV ejection fraction,[10] volumes, wall thickening by way of partial volume effects,[11] and regional asynchrony.[12] Multiple different approaches are possible in acquiring SPECT data with ECG-gating, and effects of gating errors and arrhythmias on quantified parameters have been reported.[13] By the same token, several different approaches to handle cardiac displacement to account for breathing motion are possible. With these new approaches to incorporate information regarding pulmonary motion, attention now has broadened to assessing the effects of pulmonary gating errors and breathing motion not only on myocardial perfusion but on the other parameters as well. This account by Kortelainen et al appears to be the first investigation specifically addressing pulmonary motion effects on the technical reliability of LV regional asynchrony SPECT measurements.[1]

A challenge in analyzing scintigraphic cardiac data is that the location and shape of the myocardial walls change in time both because of cardiac displacement by the lungs but also because the heart itself is changing shape, size, and position, so that dual-gating of both respiratory and ECG signals are an approach to handling

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these types of data. Some approaches have employed equipment to aid in detecting the phase of breathing motion, and others have concentrated on deriving this information from the image data itself without the use of additional external equipment. The current article employs external equipment to monitor breathing and acquires data in dual-gated list mode.[1]

The heart itself is a moving target and the details of the motion itself constitute some of the functional parameters to be quantified. But, which aspect of heart motion is of most interest? For instance, cardiac torque can be considered an annoying complication or it can be considered the main component of motion that one desires to isolate and quantify.[14] When pursuing motion correction of cardiac indices, it is important to establish not only the effect on quantified values but also on visual impression. Practically speaking, does the correction improve the physician's ability to diagnose cardiac disease, and is there a measurable clinical improvement in medical care to an individual patient? Do corrections for pulmonary motion really improve patient outcome? To answer questions of that nature, it is most straightforward to execute prospective studies. One of the features of the approach presented by Kortelainen et al is that its effect on data for normal subjects is unknown and has yet to be tested, as all subjects studied had cardiac disease. It is of course important to assess effects on specificity of the various parameters for any new computational technique applied to acquired data. This is not incidental, as the methods proposed require segregating counts into data bins and discarding half the data furthest from end-expiration, so that the signal-to-noise ratio of image data will be lower for the dual-gated data than for ECG-gated data. While the assumptions that counts will be adequate for 15 seconds per projection data will be effective for some patients, it will not be for others, such as patients with large body habitus. So, it may be that these dual-gating techniques would be more successfully implemented using a fixed count target instead of a fixed time target, to at least acquire adequate counts.[15] Doing so likely would be more feasible in a greater percent of cases if this particular dual-gating methodology were to be employed in conjunction with CZT or other solid state camera designs, because as a class, these devices acquire 3-5 times more counts than are acquired by conventional rotating Anger detectors.[16] This would more easily lend itself to pulmonary motion correction technology implemented in the current paper, which relies on discarding half the acquired counts.

It seems likely that list mode acquisitions for pulmonary data, such as the technology used in the article by Kortelainen et al,[1] will be essential as opposed to assuming a fixed breathing cycle time interval, in order to handle breathing patterns that change with time during data acquisition. One could anticipate that this would be particularly important for protocols for which the heart is imaged while actually stressed. At many institutions, myocardial perfusion analysis is assessed by summing all ECG-gated images into a single tomogram without any gating corrections at all, but alternatives exist to freeze-frame LV motion,[17] and an extension of this approach for dual-gating has been reported for PET imaging.[18] Techniques that freeze-frame the heart, mapping counts from all phases into a single breathing phase as well as a single ECG phase, may be preferable to effectively summing position counts for the first half of the respiratory cycle, which is effectively what is done by Kortelainen et al.[1]

As mentioned above, cardiac motion does not only consist of translation and contraction. There are additional motion components, including torque and hysteresis.[19] While some work has been done in nuclear imaging to detect torque,[14] considerably more has been done by echocardiography,[20] and by cardiac MRI techniques.[21] Recently pulmonary hysteresis motion has been studied by nuclear imaging,[19] but this is a relatively recent development, which previously had been investigated mainly by way of cardiac MRI.[22,23]

While the intent of the current article is to present a method to account for pulmonary effects on SPECT studies that are used to assess LV asynchrony,[1] a tantalizing prospect is that dual-gating methods now being developed may offer the prospect of investigating disease processes involving both aberrant pulmonary and cardiac function.[24] Echocardiography has been used to investigate cases of pulmonary edema induced by RV pacing,[25] and cardiac MRI has been used to detect inter-ventricular asynchrony resulting from primary arterial hypertension.[26] The added technical sophistication afforded by further developing dual-gated SPECT and PET methods may well have a role to play in uncovering more complicated interactions between different organ systems and different diseases, as it has been pointed out that both PAH and inter-ventricular asynchrony simultaneously is a complicated and serious medical condition with quite poor prognosis.[27]

Considering that recently scintigraphic imaging has been expanding to encompass further techniques to study RV asynchrony as well as LV asynchrony in conjunction with pulmonary disease,[28,29] the methods described in the current paper are timely. Whichever particular methods to detect and correct pulmonary as well as inherent cardiac components of organ motion ultimately prove to be most robust, it certainly appears that the recent technological advances have the prospect of enabling advances in understanding the mechanisms underlying observed disease states, particularly the interrelations between pulmonary diseases and cardiac diseases.

Disclosures

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