INVITED COMMENTARY

Attenuation Correction for Cardiac SPECT: Clinical and Developmental Challenges

This interesting article by Lee et al. (*1*) provides data to support what many nuclear cardiology specialists have suspected for some time: that currently implemented attenuation correction provides little or no added value to either interpretive confidence or diagnostic accuracy. Furthermore, and perhaps a point of skepticism for many, this particular study also showed no benefits of electrocardiographic gating. In an era in which providers are searching for simpler, faster, and less-expensive solutions, the results will be viewed by some as a good reason to resist electrocardiographic gating and attenuation correction with their attendant costs and complexities. Nevertheless, the inexorable march of progress will continue. Most SPECT myocardial perfusion studies are now acquired with electrocardiographic gating. The American Society of Nuclear Cardiology (ASNC) has published a position paper on its importance (*2*), and audience response at major meetings continues to indicate a strong desire for attenuation correction that works because, at present, nonuniform attenuation is generally perceived to be the most important contributor to SPECT inaccuracy.

Like other investigations of new techniques, this study on the clinical importance of attenuation correction, undoubtedly motivated by enthusiasm for a promising new technique, is of limited value because it examines performance of an incomplete method. As pointed out by the authors, our group, and others, for attenuation correction to perform optimally, correction for photopeak scatter and nonstationary resolution is also required (*3–5*). Inclusion of these corrections promises to provide additional diagnostic accuracy and quantitation over attenuation correction alone. Furthermore, for simultaneous emission–transmission imaging, compensation for ^{99m}Tc downscatter into the ^{153}Gd-derived attenuation map is essential to avoid attenuation map errors yet was not available for this evaluation (*6,7*). In this article and others, attenuation correction is assessed clinically even before quality control for transmission instrumentation performance has been adequately described. Lastly, objective normal file quantitation, which embodies technical aspects of the method and patient population characteristics, is not part of this study. With respect to attenuation correction, this article reflects results obtained when attenuation correction was applied without the benefit of a standardized environment.

By the time this article is read, much progress will have been made toward addressing these deficiencies. In fact, the ability of early attenuation correction to match the results of filtered backprojection (FBP) is remarkable when one compares the resources and infrastructure that support a SPECT study obtained with FBP reconstruction. FBP SPECT benefits from instrumentation quality-control programs that are well defined by objective industry standards (e.g., National Electrical Manufacturers Association) and are embedded in the practice of nuclear cardiology. Consequently, clinicians and technologists are empowered to make rapid and effective decisions in response to technical or patient factors with potential impact on interpretation. Standardized testing protocols adopted and incorporated into ASNC and Society of Nuclear Medicine guidelines are based on the FBP method. Interpretive confidence with FBP SPECT is further bolstered by the exclusive use of this algorithm in training programs, landmark clinical publications, and quantitative tools that objectively describe normal and abnormal patterns and assist in identifying artifacts. Read-with-the-experts and interpretive workshops intrinsically use FBP SPECT images. Attenuation correction, therefore, has a formidable opponent, as positioned in most clinical evaluations, whose strength is based on years of experience and well-developed adjunctive methods. Comparing FBP SPECT and new attenuation correction methods using conventional measures of accuracy is naturally biased toward FBP SPECT and its interpretive preference. This may help explain why early investigations with attenuation correction performed in highly sophisticated laboratories produced very favorable results (*8,9*) but were not readily reproduced in other clinical settings. However, recent published results suggest that the real world performance of attenuation correction is improving for a range of manufacturers' systems and techniques (*10–17*).

Investigators who work closely with attenuation correction have not adequately communicated to clinicians that the quality of the transmission data and resulting attenuation map can significantly affect the quality of the study; we believe that critical evaluation of these data as part of the acquisition or interpretive process is not performed at most sites. Our own unpublished evaluation of studies acquired at prominent sites with the system used in this investigation showed significant deficiencies in data quality. Most common of these were truncation of the transmission projections (*18*); low counts in the

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For correspondence or reprints contact: S. James Cullom, PhD, Cardiovascular Consultants, PC, 4330 Wornall Rd., Ste. 2000, Kansas City, MO 64111.

transmission projections, producing unacceptable bias and variance in the attenuation map (*19*); and inconsistent reference scan normalization that can occur between the frames of an acquisition and between studies. Our evaluation also showed that transmission images acquired simultaneously with electrocardiographic gating could have streaking artifacts that can corrupt the attenuation map in studies with significant beat rejection. These factors likely played a part in the initial experience and reporting of results with attenuation correction.

This experience points to the direction for needed development. Important considerations are required at all steps of the imaging protocol: preacquisition, postacquisition, and interpretation. As part of the daily quality-control protocol, performance of the transmission scanning capabilities should be evaluated along with conventional performance parameters. This should include reference scan uniformity, tracking of line source strength, and methods to ensure that sufficient transmission count density is obtained on a patient-specific basis. Tools that assist in identifying and characterizing potential sources of artifact could provide important technical information to assist in interpretation as well as feedback for consistent quality improvement of scans. Working with the manufacturer of the system used in this study, we have developed tools that perform a brief planar scan before the study for estimation of scanning time to ensure sufficient count density. On the postacquisition side, algorithms have been developed to interrogate the data and assist in recognizing potential technical problems that may affect study quality (*20*). This information is now incorporated into the interpretation process as adjunctive information. Tools specific for the display and analysis of attenuation correction data should also be developed to minimize the bias in comparison with conventional methods. Artifacts sometimes occur in attenuation correction studies and are a combination of algorithm characteristics, patient-related factors, hardware performance, and interpretive experience. These artifacts must be predictable, and addressing quality control is an important step toward this goal.

The incremental value of electrocardiographic gating to improve diagnostic accuracy was also investigated in this article. Improved diagnostic accuracy that is mainly associated with an increase in specificity has been reported (*21*). However, as the authors point out, this increment is likely to be dependent on the study population and related to factors such as the prevalence of diaphragm and breast attenuation, the severity and extent of coronary artery disease (CAD), prior history of CAD, and prior infarction. This study does not reveal the prevalence of attenuation problems in the FBP images, and the patients were not known to have CAD (mean CAD likelihood, 60%). Furthermore, 38% of the patients had multivessel CAD (a subset not particularly challenging for FBP SPECT), and another 43% were considered normal. Only 13 patients had single-vessel CAD, a subset more problematic to experienced readers and in which prior studies have shown suboptimal sensitivity and specificity. Electrocardiographic gating is useful for several reasons besides improving diagnostic accuracy: measurement of left ventricular ejection fraction (LVEF) and volumes; determination of transient regional wall motion abnormalities presumably associated with myocardial stunning; and, when performed after stress and at rest, recognition that a lower LVEF after stress than at rest in conjunction with an extensive transient wall motion abnormality likely identifies a higher risk patient.

In evaluating the clinical value of a diagnostic test, recent attention has changed from accuracy as a gold standard (such as coronary angiography) to impact on patient management. How well does myocardial perfusion imaging perform today in the absence of these newer adjuncts? In this group of 68 patients referred for possible CAD and with a pretest likelihood averaging 60%, it could be argued that approximately 62% (the 29 considered normal and 13 with single-vessel CAD) were referred inappropriately for catheterization. Extensive literature now indicates the need for a gatekeeper to the catheterization laboratory. This study suggests that SPECT without refinement does not perform well in all clinical situations and in all settings.

It is interesting to speculate on the potential additive implications of attenuation correction and electrocardiographic gating on subsequent patient management decisions. Both, when performed optimally, should lend a measure of interpretive confidence that would lead to a greater reliance on the findings in subsequent clinical decisions. Optimally, very few patients with normal, near-normal, or mildly abnormal scans would be referred for angiography. It is now well known that revascularization is of most benefit in patients with multivessel or proximal left anterior descending coronary artery distribution ischemia; the excess referral for angiography after scans reveal ischemic extent and severity of lesser degrees most likely reflects a lack of confidence in the results.

We are of the opinion that SPECT myocardial perfusion imaging has come a long way but has much potential yet to develop. Electrocardiographic gating and attenuation correction are 2 important advances. In fact, they are generally perceived to be so important that they have been incorporated into clinical practice very early in their technical development. Although ongoing evaluation of performance in clinical settings is always of interest, it is likely that history will document that both of these techniques will become routine and make valuable contributions to the diagnosis and management of patients with CAD.

S. James Cullom
James A. Case
Timothy M. Bateman
Cardiovascular Consultants, PC, and Mid America Heart Institute
Kansas City, MO

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