The Value and Practice of Attenuation Correction for Myocardial Perfusion SPECT Imaging: A Joint Position Statement from the American Society of Nuclear Cardiology and the Society of Nuclear Medicine

Robert C. Hendel, MD; James R. Corbett, MD; S. James Cullom, PhD; E. Gordon DePuey, MD; Ernest V. Garcia, PhD; and Timothy M. Bateman, MD

Despite advancements in technologies, non-uniform soft tissue attenuation still affects the diagnostic accuracy of single photon emission computed tomography (SPECT) myocardial perfusion imaging. A variety of indirect measures have been used to reduce the impact of attenuation, most notably electrocardiography-gated SPECT imaging. However, all available techniques have limitations, making interpretation in the presence of attenuation difficult. The ultimate solution, similar to positron emission tomography imaging, is to use hardware/software algorithms to eliminate attenuation and provide images that are more uniform and easier to interpret. Several attenuation correction solutions are currently available and more will be available soon. The value of these solutions has been varied, particularly with clinical applications. Guidelines and standards clearly are necessary.

In recognition of the importance of this issue, the American Society of Nuclear Cardiology and the Society of Nuclear Medicine convened a joint task force to develop a position statement on attenuation correction. It is being published concurrently in the *Journal of Nuclear Cardiology* and *The Journal of Nuclear Medicine*, a first for these societies.

The purpose of this position statement is to clarify the role of attenuation correction in SPECT procedures, to provide guidelines for its clinical use, and to provide a basis for the evaluation of published validation. It is hoped that this position statement will provide an important and useful road map to the widespread adoption of attenuation correction into clinical practice.

Gary V. Heller, MD, PhD
President, American Society of Nuclear Cardiology

Alan Maurer, MD
President, Society of Nuclear Medicine

For correspondence or reprints contact: Society of Nuclear Medicine, 1850 Samuel Morse Dr., Reston, VA 20190-5316.

Reprinted with permission of the American Society of Nuclear Cardiology from the *Journal of Nuclear Cardiology*, Jan./Feb. 2002, Vol. 9, No. 1, pp. 135–143.

Key Words: attenuation correction; SPECT; myocardial perfusion; guidelines

J Nucl Med 2002; 43:273–280

PREAMBLE

The diagnostic accuracy of single photon emission computed tomography (SPECT) myocardial perfusion imaging is profoundly influenced by the presence of tissue attenuation. Although interpretative education, experience, and the application of gated SPECT imaging have had a favorable impact on the clinical value of radionuclide perfusion imaging, the nuclear cardiology community has long-awaited correction techniques for photon attenuation. The purposes of this statement are to review the recent developments in the field of attenuation correction, to define its clinical utility, and to delineate contemporary recommendations regarding attenuation correction techniques.

BACKGROUND

Soft tissue attenuation, Compton scatter, and depth-dependent reduction of spatial resolution degrade myocardial perfusion SPECT image quality, thereby decreasing test sensitivity in the detection of coronary artery disease. In addition, localized soft tissue attenuation by the breasts, lateral chest wall, abdomen, and left hemidiaphragm may create artifacts that mimic true perfusion abnormalities and thereby decrease test specificity.

Conventional SPECT imaging has used a variety of techniques to minimize the impact of attenuation, including breast binding, prone imaging, and electrocardiography-gated SPECT imaging. However, each technique is an indirect solution and possesses specific limitations. For example, normal regional wall motion on a gated SPECT study after stress is not helpful in distinguishing artifact from ischemia in the presence of a reversible perfusion defect. Therefore gated SPECT and other methods fail to provide a universal solution for attenuation artifacts.

The diagnostic accuracy of conventional SPECT is also compromised by artifacts associated with localized subdiaphragmatic tracer concentration in the abdominal viscera, including the liver, stomach, and bowel. Such visceral activity that approximates the heart may scatter into the adjacent left ventricular walls, resulting in artifactually increased associated count densities. Alternatively, intense visceral tracer concentration may result in a ramp filter (negative lobe) artifact, which results in decreased count densities adjacent to "hot" objects.

TECHNIQUES

Several types of systems with transmission hardware modifications and external sources have emerged for clinical implementation. They predominantly use gadolinium 153 (100 keV) as the external source but may use cobalt 57 (122 keV), barium 133 (360 keV), americium 241 (60 keV), and technetium 99m (140 keV). The main configurations (Figure 1) are (1) fixed line source with convergent collimation on a triple-detector system, (2) scanning line sources with parallel-hole collimation on dual 90° systems, (3) the multiple line source array approach with parallel-hole collimation on 90° dual-detector systems, (4) scanning point sources on dual- and triple-detector systems, and (5) rotating x-ray tube–based technology on dual-detector systems. Each system has unique attributes and limitations. The fixed line source with convergent geometry provides highly efficient transmission image acquisition that allows the use of comparatively low source strength. The limited field of view of convergent collimation can cause regions of the body to be outside of the field of view for some projection images, leading to truncation artifacts that may limit the accuracy of attenuation correction, unless highly sophisticated iterative reconstruction algorithms are used to minimize these effects.

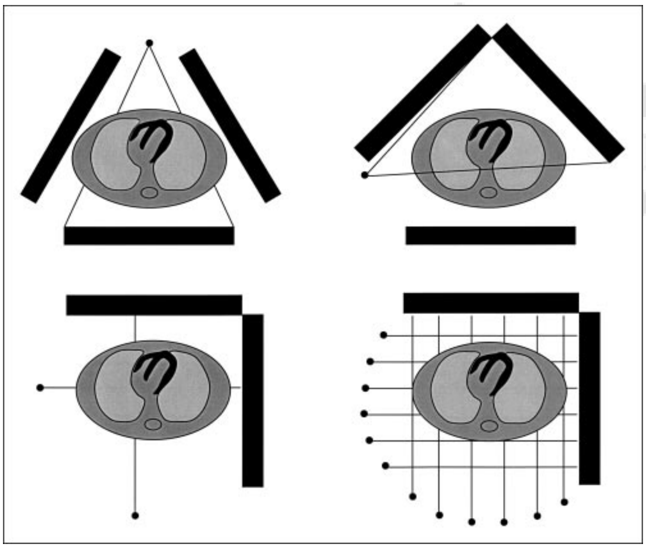

FIGURE 1. Commercial configurations for SPECT-based transmission imaging for cardiac attenuation-corrected myocardial perfusion imaging: fan-beam (A), off-axis (B), scanning line source (C), and source array (D).

The most widely implemented configuration for commercial transmission acquisition is the scanning line source geometry on 90° dual-detector SPECT systems. This approach has collimated line sources that scan mechanically across the field of view at each angle and project onto the opposing detector, where an electronic window moves opposite the source to accept transmission photons. These systems have a maximum field of view, thereby minimizing the likelihood of patient truncation. The electronic window provides maximal separation of the emission and transmission images. Scanning hardware requires careful monitoring because some systems are prone to mechanical instability.

The multiple line source array approach uses groups of collimated line sources mounted on the gantry opposite the detectors for transmission image acquisition. This method provides highly efficient measurement geometry without the need for additional mechanical motion. The photon flux from the collimated source arrays spans the field of view of each opposing detector. The continuous incidence of the transmission source photons over the fields of view for both detectors with this geometry can cause significant crosstalk from downscatter with thallium 201 imaging requiring interleaved or sequential emission-transmission imaging.

A system that uses a conventional x-ray tube and detector mounted on a large–field-of-view SPECT gantry has recently been introduced. The photon flux is very high with this approach, yielding high-quality attenuation maps. This system was developed largely for anatomic registration with emission images for oncology studies but should have application in attenuation correction of cardiac images. A system that uses scanning point sources of Ba-133 (360 keV) has recently become available. The point sources are collimated, but the holes of the detectors are not aligned with the focal point of each source. The high-energy emissions from these sources penetrate the low-energy collimators' septa, forming the transmission projections from which the attenuation map is reconstructed.

CLINICAL TRIALS

Several clinical trials have now been presented in the literature (Table 1). One of the most encouraging methods was used by Ficaro and colleagues, who reported the results of attenuation correction in phantoms and patient cohorts using a 3-detector system equipped with 2 parallel-hole collimators for collection of emission data and a third detector with a fan-beam collimator to acquire the transmission data from an Am-241 line source. They demonstrated significant improvement in diagnostic accuracy in 60 patients with Tc-99m sestamibi SPECT imaging, with a marked improvement in specificity

TABLE 1
Diagnostic Value of Attenuation Correction Systems

Author	System	*n*	Sensitivity (%)		Specificity (%)		Normalcy (%)	
			NC	AC	NC	AC	NC	AC
Ficaro	U Mich	119	78	84	48	82	88	98
Hendel	ADAC	200	76	78	44	50	86	96
Links*	SMV	112	84	88	69	92	69	92
Gerson**	Picker	113	85	90	NA	NA	72	70
Gallowitsch	Elscint	49	89	94	69	84	NA	NA
Lenzo**	Siemens	171	93	93	84	88	78	85
Composite		764	81	85	64	81	80	89

NC = Non–attenuation-corrected SPECT; AC = attenuation-corrected SPECT; NA = not available.
*Includes motion correction and depth-dependent blur correction.
**Includes scatter correction.

(from 48% to 82%). Similarly, in a group of 59 patients with a low likelihood of coronary artery disease, an increase in the normalcy rate from 88% to 98% was demonstrated. Although the increase in test sensitivity was not statistically significant, there were significant increases in sensitivity for individual vessels overall (63% vs. 78%) and in 2 of 3 vascular territories.

The method used in the above trial was subsequently compared in 171 patients with the commercially available technique that uses the multiple line source array method for acquiring the transmission maps (Profile, Siemens). Profile attenuation correction demonstrated improved diagnostic specificity by patient, as well as sensitivity and accuracy for individual coronary arteries. Attenuation correction also demonstrated statistically significant increases in normalcy rates. The overall sensitivity by patient was similar with both the corrected and uncorrected images.

The first prospective multicenter trial was performed by Hendel et al. using a commercially available 90° dual-detector system with a scanning Gd-153 line source (Vantage, ADAC Laboratories). The diagnostic sensitivity (n = 96) for the detection of 50% or greater stenoses was similar with the use of uncorrected perfusion data or attenuation- and scatter-corrected data. The normalcy rate (n = 88), however, was significantly improved (86% vs. 96%, respectively), and false-positive perfusion images were reduced by more than 4-fold (from 14% to 4%). Furthermore, observer confidence for the presence or absence of image normalcy was increased, as reflected in the visual diagnostic scores. Regional differences were noted with reduced sensitivity but improved specificity for right coronary lesions through use of attenuation-scatter correction methods. However, the ability to detect multivessel disease was reduced with attenuation-scatter correction, which may have important prognostic implications.

Gallowitsch et al. studied 107 patients with known or suspected coronary artery disease with Tl-201 imaging using another dual-detector system equipped with a scanning Gd-153 line source and an iterative Chang reconstruction algorithm (Transact, Elscint). There were no significant improvements in diagnostic accuracy noted in this trial, although specificity was somewhat improved with attenuation correction, from 69% for non–attenuation-corrected SPECT to 84% for attenuation-corrected SPECT (P = not significant).

Another multicenter trial was recently completed by Links et al. using a similar system (TAC/Restore, SMV), in which the transmission data were acquired with a scanning Gd-153 source for Tc-99m emissions and a Tc-99m transmission source for Tl-201 emission imaging. The imaging algorithm incorporated a motion correction algorithm along with attenuation correction and depth-dependent resolution compensation. These investigators demonstrated significant gains in overall specificity (from 69% to 92%; P = .002) and in all 3 coronary territories. In addition, normalcy increased from 74% to 91% (P = .04) with combined attenuation, motion, and blur correction, and test sensitivity demonstrated a slight but insignificant increase from 84% to 88% (P = not significant).

Additional clinical trials are under way that are using second-generation systems (Vantage Pro, ADAC Laboratories), as well as new approaches for transmission map generation including the translucent collimator with high-energy photons (Ba-133) (Beacon, Marconi) described earlier. Hybrid systems, such as those that use x-ray computed tomography–generated transmission maps, may provide high-quality transmission maps as a result of the high count density and spatial resolution that these systems provide (Hawkeye, GE Medical Systems).

The impact of attenuation correction on the detection of coronary artery disease within a specific vascular territory is variable (Figures 2 and 3). Several studies have shown a substantial improvement in specificity for right coronary artery disease, but occasionally with a loss of sensitivity in either right coronary artery or left anterior descending coronary artery distribution. The promise of enhanced sensitivity is yet to be realized clinically, although a recent phantom study demonstrated that defect detection is improved with attenuation correction. In addition, some trials

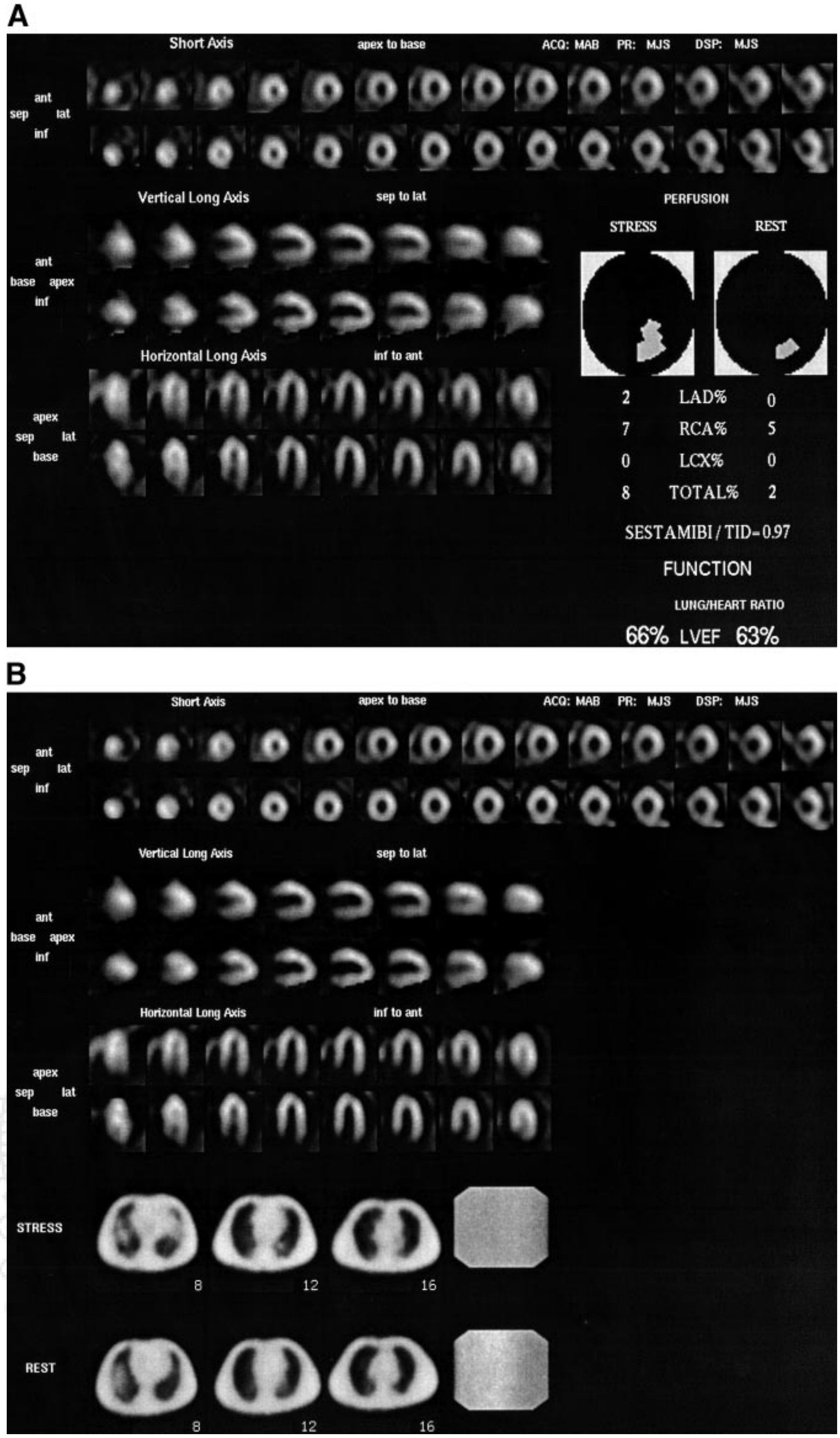

FIGURE 2. (A) Exercise-rest Tc-99m sestamibi SPECT study, suggestive of ischemia in the inferior, inferolateral, and inferoseptal regions but confounded by the presence of possible subdiaphragmatic attenuation. (B) After attenuation correction, the SPECT study demonstrates definite ischemia in the distribution of the right coronary artery. Attenuation map samples and daily reference scans are shown for quality control.

have demonstrated that attenuation correction enables improved recognition of multivessel and left main disease. Complete and accurate correction for attenuation and scatter would be a major step toward the long-held promise of absolute perfusion quantification and the enhanced diagnostic accuracy it would afford, especially in the setting of “balanced” 3-vessel disease.

Quantitative analysis programs specific for each camera system and radiopharmaceutical are limited but are under active development. It is anticipated that quantitative reference (normal) databases will be available for each manufacturer’s system. Ideally, these databases obtained from healthy subjects should be gender-independent, assuming total correction for attenuation.

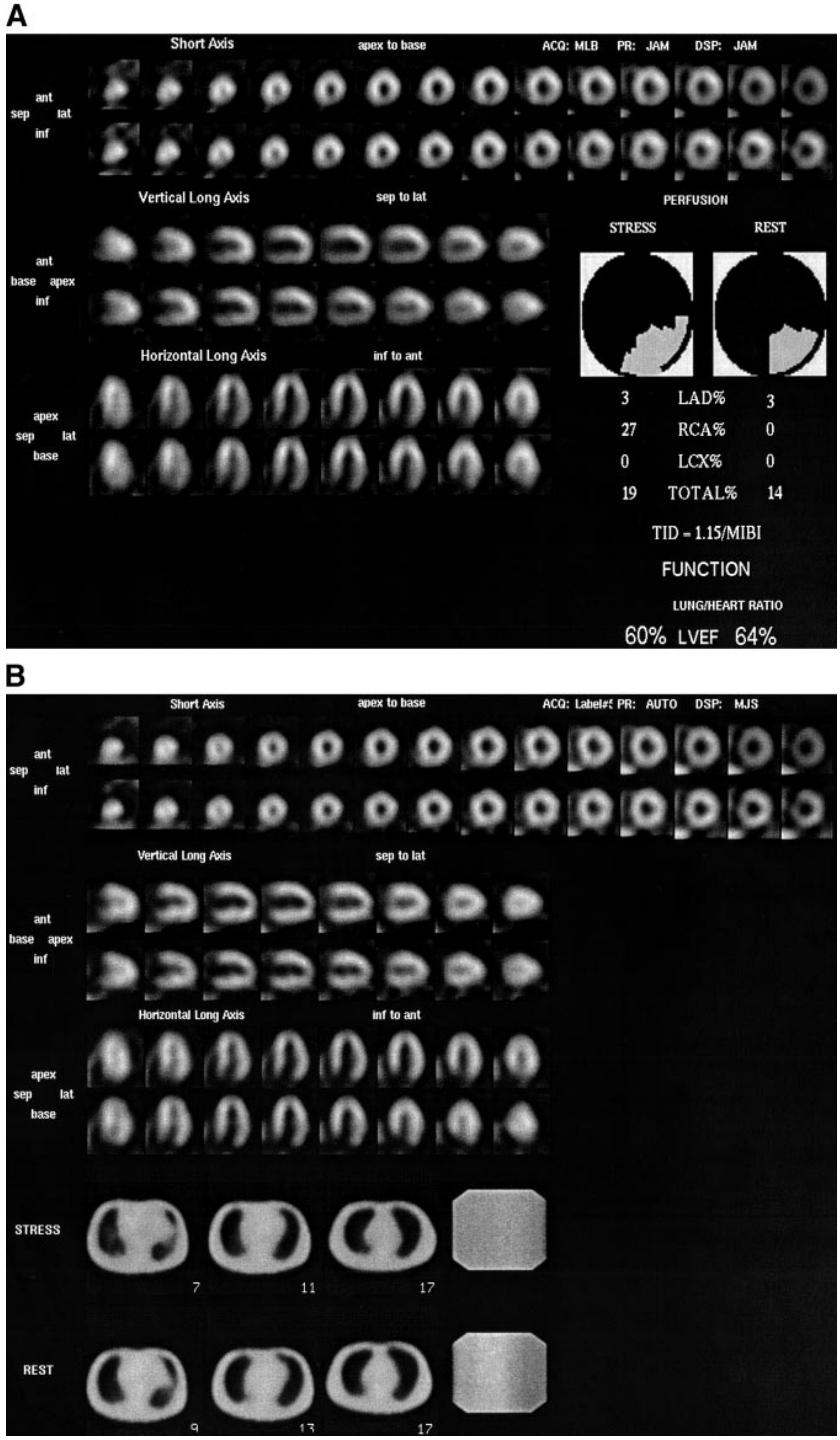

FIGURE 3. (A) Exercise-rest Tc-99m sestamibi SPECT study in a large man depicting a persistent reduction of activity in the inferior and inferolateral regions of the left ventricle, suggestive of a prior infarction. (B) Attenuation-corrected images reveal normal perfusion in all regions. Attenuation map samples and daily reference scans are shown for quality control.

Attenuation correction may have substantial value for specific applications beyond the detection of coronary artery disease (Table 2). Preliminary data reveal superior diagnostic performance in the triage of emergency department patients with chest pain. Attenuation-corrected SPECT images have demonstrated the ability to better detect areas of viable myocardium, correlate better with positron emission tomography imaging, and provide improved prediction of functional recovery after revascularization. Attenuation correction also possesses the potential to further improve the prognostic value of myocardial perfusion imaging, as patients with soft tissue attenuation artifacts may be more accurately categorized as being at low risk for cardiac events. The use of attenuation and scatter correction tech-

TABLE 2
Clinical Value of Attenuation Correction

Confirmed	Potential
Improved artifact recognition	Increased sensitivity
Higher specificity	Improved recognition of MVD and LM
Higher normalcy rates	Enhanced prognostic value
Increased reader confidence	Stress-only imaging
Acute-use applications	Absolute flow quantitation

MVD = multivessel coronary disease; LM = left main coronary disease.

niques may be especially valuable for less-experienced interpreters of myocardial perfusion studies, with improvements in both sensitivity and overall diagnostic accuracy demonstrated in some studies for this group of interpreters.

QUALITY CONTROL

Experience with SPECT myocardial perfusion data processed with filtered backprojection has led to widespread appreciation of the importance of quality control measures. Attenuation correction introduces a number of additional quality issues that, if not addressed systematically and satisfactorily, will translate into suboptimal and in some cases clinically misleading image data (Table 3). Over the past several years, it has become increasingly apparent that accurate attenuation correction is dependent upon high-quality transmission images, and to ensure accuracy, appropriate quality control measures have been developed. In particular, count densities must be sufficient to overcome the intrinsic inconsistencies of scans with poor signal-to-noise ratios. Other important quality control issues related to the creation of transmission maps include body truncation, patient motion, scaling of attenuation coefficients to the correct tissue densities, accurate registration of attenuation maps and emission data, and gating artifacts unique to attenuation correction processing, especially with scanning transmission source systems. Objective measurements of these technical factors are crucial to the accuracy of attenuation correction. Automated quality control procedures should be provided by each vendor and routinely used.

Correct windowing of relevant photopeaks for attenuation-corrected SPECT imaging is also essential. Besides the energy window of the main emission photon, additional windows are required for transmission data and for scatter and crosstalk measurements; scatter and crosstalk between transmission and emission photopeaks significantly degrade the quality of the attenuation map.

Reference transmission scans should be performed daily to ensure optimal equipment performance and should include quantitative analysis. In addition, each manufacturer should provide automatic safeguards to ensure that the transmission and emission data are reconstructed properly. Finally, education of technologists, physicists, and interpreting physicians is an essential component of the quality assurance process.

Therefore quality control should include each of the following for the performance of attenuation correction: criteria for uniformity, variability, and temporal drift of the reference transmission scan; consistency of hardware performance; pre-scanning methods to ensure sufficient transmission scan counts; and algorithms that assist the operator and interpreting physician in assessing the sufficiency of the data. Although these tools are essential to all commercial methods of attenuation correction, implementation of many of the aforementioned quality control techniques has not been incorporated in the current releases of all available attenuation correction protocols. Furthermore, quality control of transmission data and attenuation-corrected reconstructed images should be performed for each patient.

SCATTER CORRECTION AND DEPTH-DEPENDENT RESOLUTION

Attenuation-corrected images, although usually of higher diagnostic quality than uncorrected images, need to be corrected for scattered photons coming from activity in structures near the heart, such as the liver and intestines. These scatter photons may result in regional overcorrection following attenuation correction techniques. The planar transmission images also must be corrected for scatter into the energy window of the transmission source because failure to perform scatter correction may result in undercorrection for attenuation.

Simultaneous emission-transmission acquisition methods must address crosstalk from downscattering of photons from the emission or transmission photopeaks (whichever is higher). Crosstalk minimization is accomplished through the geometric design of the transmission sources and detectors and consideration of the position of the patient and possible scattering angles. Software methods applied after image acquisition may be used to correct for crosstalk with data collected in additional energy windows. In order to perform attenuation, scatter, and crosstalk correction, 3 or 4 independent energy windows for data must be collected: one window for the emission information (perfusion photopeak energy); a second window for transmission data (photopeak of transmission source); a third window for scatter, positioned between the other windows; and in some systems, a fourth window, slightly above the emission win-

TABLE 3
Quality Control Methods for Attenuation Correction

Ensure adequate count density
Recognition of truncation
Appropriate gating
Correct photopeak windowing
Recognition of patient motion
Transmission scan uniformity

dow, used in conjunction with the third window to estimate scatter.

In addition to correcting for attenuation, some methods correct for photopeak scatter and the variable distance-dependent spatial resolution from the collimator. These are primarily software implementations that use additional "scatter" information acquired simultaneously with the emission data, models of the distance-dependent collimator effects, and knowledge of the orbital position of the detectors. Scatter compensation may be performed by mapping photons back to their point of origin; although promoting less noise propagation, this approach may require substantial computation time.

Image degradation is related to increasing cross-sectional area detected by each collimator hole with distance (depth) from a radioactive source, thereby creating a loss of resolution with increasing object distance away from the collimator. The use of iterative correction algorithms may be applied for Compton scatter, photon attenuation, and depth-dependent resolution to achieve higher contrast between perfusion defects and more uniformly distributed counts within normal myocardium. One commonly employed method for such compensation is the use of collimator- and energy-dependent pre-processing filters.

CONCLUSION

Attenuation correction SPECT techniques represent a significant advance in myocardial perfusion imaging and hold great promise for improved assessment of cardiac patients. Substantial technical advances have been made in the past several years, including the recognition of the importance of effective quality control and the continued development of scatter correction and resolution compensation. Advanced SPECT perfusion imaging systems, including features such as attenuation correction, must undergo complete system characterization, development of normal activity distribution profiles, and definition of differences among various manufacturers' solutions. Finally, quantitative analysis programs adapted for each camera system and radiopharmaceutical are limited but are under active development. Ideally, reference databases from healthy subjects should be gender-independent after total correction for attenuation.

Clinical validation has been performed for several but not all commercially available systems, although "complete" correction still does not occur in all patients. The true value of these methods to improve diagnostic accuracy compared with other techniques has yet to be fully defined. Attenuation correction methods offer the potential for improved diagnostic accuracy but require a modified approach to image interpretation accounting for the effects of these methods on the resultant images. Technologist and physician education in the details of these advanced imaging techniques, along with effective quantitative tools and improved processing algorithms, will continue to advance the value and acceptance of attenuation-corrected SPECT imaging.

RECOMMENDATIONS

On the basis of the available clinical evidence and the rapid development of attenuation correction technology, it is recommended that providers (institutions and practitioners) consider the addition of hardware and software that have undergone clinical validation and include appropriate quality control tools to perform non-uniform attenuation correction. Currently, it is suggested that both noncorrected and corrected image sets be reviewed and integrated into the final report. However, as the reader gains the appropriate experience and confidence in correction methodology, only the corrected images may be necessary, as is the standard in positron emission tomography. On the basis of current information and the rate of technology improvement, the Society of Nuclear Medicine and the American Society of Nuclear Cardiology believe that attenuation correction should be regarded as a rapidly evolving standard for SPECT myocardial perfusion imaging. Therefore it is our recommendation that the adjunctive technique of attenuation correction has become a method for which the weight of evidence and opinion is in favor of its usefulness.

ACKNOWLEDGMENT

We thank James Udelson, MD, and Jonathan Links, PhD, for their assistance and support for this project. The authors have indicated they have no financial conflicts of interest, unless stated otherwise in the Appendix.

SELECTED REFERENCES

Almquist, H, Arvidsson AH, Pahlm O, Palmer J. Clinical implications of down-scatter in attenuation-corrected myocardial SPECT. *J Nucl Cardiol.* 1999;6:406–11.

Chouraqui, P, Livschitz S, Sharir T, et al. Evaluation of an attenuation correction method for thallium-201 myocardial perfusion tomographic imaging of patients with low likelihood of coronary artery disease. *J Nucl Cardiol.* 1998;5:369–77.

Corbett JR, Ficaro EP. Clinical review of attenuation-corrected cardiac SPECT. *J Nucl Cardiol.* 1999;6:54–68.

Cullom SJ, Case JA, Bateman TM. Attenuation correction of cardiac SPECT: clinical and developmental challenges. *J Nucl Med.* 2000;41:860–2.

DePuey EG, Garcia EV. Optimal specificity of thallium-201 SPECT through recognition of imaging artifacts. *J Nucl Med.* 1989;30:441–9.

Duvernoy CS, Ficaro EP, Karabajakian MZ, Rose PA, Corbett JR. Improved detection of left main coronary artery disease with attenuation-corrected SPECT. *J Nucl Cardiol.* 2000;7:639–48.

Ficaro EA, Fessler JA, Ackermann RJ, Rogers WL, Corbett JR, Schwaiger M. Simultaneous transmission-emission thallium-201 cardiac SPECT: effect of attenuation correction on myocardial tracer distribution. *J Nucl Med.* 1995;36:905–6.

Ficaro EA, Fessler JA, Shreve PD, Kritzman JN, Rose PA, Corbett JR. Simultaneous transmission/emission myocardial perfusion tomography: diagnostic accuracy of attenuation corrected Tc-99m sestamibi single-photon emission computed tomography. *Circulation.* 1996;93:463–73.

Ficaro E, Duvernoy C, Karabajakian M, Corbett J. Evaluation of attenuation corrected SPECT perfusion imaging in patients with multi-vessel disease [abstract]. *Circulation.* 1997;96:I–308.

Gallowitsch HJ, Sykora J, Mikosch P, et al. Attenuation-corrected thallium-201 single-photon emission tomography using a gadolinium-153 moving line source: clinical value and the impact of attenuation correction on the extent and severity of perfusion abnormalities. *Eur J Nucl Med.* 1998;25:220–8.

Gallowitsch HJ, Unterweger O, Mikosch P, et al. Attenuation correction improves the detection of viable myocardium by thallium-201 cardiac tomography in patients with previous myocardial infarction and left ventricular dysfunction. *Eur J Nucl Med.* 1999;26:459–66.

Garcia EV. Quantitative myocardial perfusion single-photon emission computed tomographic imaging: quo vadis? (Where do we go from here?) *J Nucl Cardiol.* 1994;1:83–93.

Gerson MC, Singh BKM, Lukes J, Bauman BD. Comparison of attenuation and Compton scatter corrected to uncorrected thallium-201 tomograms for diagnosis of coronary artery disease (CAD) [abstract]. *J Nucl Med.* 1999;40:89P.

Hendel RC, Berman DS, Follansbee W, Heller GV, Cullom SJ. A multicenter clinical trial to evaluate the efficacy of correction for photon attenuation and scatter in SPECT myocardial perfusion imaging. *Circulation.* 1999;99:2742–9.

Hendel RC, Selker HR, Heller GV, et al. The impact of attenuation correction and gating on SPECT perfusion imaging in patients presenting to the emergency department with chest pain [abstract]. *Circulation.* 2000;102:II–543.

Jaszczak RJ, Greer KL, Floyd CG, Harris CG, Coleman E. Improved SPECT quantification using compensation for scattered photons. *J Nucl Med.* 1984;25:893–900.

Kadrmas DJ, Frey EC, Tsui BMW. Application of reconstruction-based scatter compensation to thallium-201 SPECT: implementations for reduced reconstruction image noise. *IEEE Trans Med Imaging.* 1998;17:325–33.

King MA, Tsui BMW, Pan TS. Attenuation compensation for cardiac single-photon emission computed tomographic imaging: part 1. Impact of attenuation and methods of estimating attenuation maps. *J Nucl Cardiol.* 1995;2:513–524.

King MA, Tsui BMW, Pan TS, Glick SJ, Soares EJ. Attenuation compensation for cardiac single-photon emission computed tomographic imaging: part 2. Attenuation compensation algorithms. *J Nucl Cardiol.* 1996;3:55–63.

Kluge R, Sattler B, Seese A, Knapp WH. Attenuation correction by simultaneous emission-transmission myocardial single-photon emission tomography using a technetium-99m-labelled radiotracer: impact on diagnostic accuracy. *Eur J Nucl Med.* 1997;24:1107–1114.

Lacroix KJ, Tsui BMW, Frey EC, Jaszcak RJ. Receiver operating characteristic evaluation of iterative reconstruction with attenuation correction in Tc-99m sestamibi myocardial perfusion SPECT images. *J Nucl Med.* 2000;41:502–513.

Lee DS, So Y, Cheon GJ, et al. Limited incremental diagnostic values of attenuation noncorrected gating and ungated attenuation correction to rest/stress myocardial perfusion SPECT in patients with an intermediate likelihood of coronary artery disease. *J Nucl Med.* 2000;41:852–859.

Lenzo N, Ficaro, NP, Kritzman JN, Corbett JR. Clinical comparison of Profile attenuation correction and the Michigan modified STEP methods [abstract]. *J Nucl Cardiol.* 2001;8:S19.

Links JM, Becker LC, Rigo P, et al. Combined corrections for attenuation, depth-dependent blur, and motion in cardiac SPECT: a multicenter trial. *J Nucl Cardiol.* 2000;7:414–425.

Matsunari I, Boning G, Ziegler SI, et al. Attenuation-corrected Tc-99m tetrofosmin single-photon emission computed tomography in the detection of viable myocardium: comparison with positron emission tomography using F-18 fluorodeoxyglucose. *J Am Coll Cardiol.* 1998;32:927–935.

Matsunari I, Boning G, Ziegler SI, et al. Attenuation corrected rest thallium-201/stress technetium 99m sestamibi myocardial SPECT in normals. *J Nucl Cardiol.* 1998;5:48–55.

Miles J, Cullom SJ, Case JA. An introduction to attenuation correction. *J Nucl Cardiol.* 1999;6:449–457.

Prvulovich EM, Lonn AHR, Bomnji JB, Jarritt PH, Ell PJ. Effect of attenuation correction on myocardial thallium-201 distribution in patients with a low likelihood of coronary artery disease. *Eur J Nucl Med.* 1997;24:266–275.

Vidal R, Buvat I, Darcourt J, et al. Impact of attenuation correction by simultaneous emission/transmission tomography on visual assessment of Tl-201 myocardial perfusion images. *J Nucl Med.* 1999;40:1301–1309.

APPENDIX

The Boards of Directors of the American Society of Nuclear Cardiology and the Society of Nuclear Medicine have reviewed and approved this position statement with the belief that it provides balanced and objective information on the value of attenuation correction for myocardial perfusion SPECT imaging. However, to ensure that the most recent information and diverse perspectives on attenuation correction were included in this statement, individuals with potential conflicts of interest participated in the development of this document. The following contributing authors have provided declarations of potential conflicts of interest as listed and have excluded themselves from the final position statement review and approval process: Timothy M. Bateman, MD, stock ownership (Cardiovascular Consultants Imaging Technologies, Inc) and research grants (ADAC Laboratories, Inc, and Dupont Pharmaceuticals), and S. James Cullom, PhD, and Ernest V. Garcia, PhD, royalties from the sale of ExSPECT II software (ADAC Laboratories, Inc).