A simple method for calculating the trade-off between noise / sampling error and interval number in gated SPECT.

G Currie, J Wheat, H Kiat

Citation

G Currie, J Wheat, H Kiat. *A simple method for calculating the trade-off between noise / sampling error and interval number in gated SPECT.*. The Internet Journal of Cardiology. 2008 Volume 7 Number 2.

Abstract

Sir:

The introduction of cardiac gating to the myocardial perfusion SPECT (single photon emission computed tomography) study affords the ability to simultaneously assess both myocardial perfusion and function (1). The ease of its application for image acquisition, processing and display and automatic quantitation capabilities assured its rapid and widespread clinical implementation. While gating myocardial perfusion SPECT offers physical and clinical advantages that are well recognised, the improved temporal resolution over non gated SPECT may come at the expense of a deteriorating signal to noise ratio (SNR) (2). That is, gated SPECT results in lower count density per individual frame compared to the same SPECT acquisition without gating by a factor equal to the number of gate intervals. Not only does a poor SNR have an adverse effect on image quality but the lower count statistics also result in greater statistical uncertainty for data entering mathematical reconstruction.

SPECT reconstruction and filtering complicate calculations of SNR because the processed data are no longer comprised of pixels independent from one another (3). Thus, the following equation is used to determine the reconstructed SNR for data reconstructed using a ramp filter:

Figure 1

$$SNR = \frac{\sqrt{N_R}}{\sqrt[4]{R}}$$

where N_R is the reconstructed counts per pixel and R is the number of pixels containing activity (3). Applying this equation, an eight interval gated SPECT, over a 64 x 64 matrix (assuming no beat rejections) results in a reconstructed SNR deterioration by a factor of 2.83 for over the non-gated data.

Sampling error (SE) is proportional to the inverse of the square root of the sample size (N) such that:

Figure 2

$$SE \propto \frac{1}{\sqrt{N}}$$

When N is reduced by a factor of eight as is the case with gated SPECT, there is a corresponding increase in sampling error by a factor of 2.83.

It is clear that using an eight interval gate both increases sampling error and decreases SNR by a factor of 2.83 and one might note that 2.83 is the square root of eight. This observation provides a very useful tool, for both the nuclear cardiologist and the cardiac technologists alike, in making informed judgement decisions regarding the trade-off between temporal resolution and data integrity. Complex calculations can be determined with greater simplicity to determine the trade-off in image quality (SNR) and statistical certainty for any number of gate intervals. For example, using a 16 interval gate would deteriorate SNR and sampling error by a factor of four; the square root of 16. A more practical application, however, relates to increasing the number of gate intervals which should, in theory, improve the accuracy of volume and ejection fraction calculations. Changing from an eight interval gate to a 16 interval gate will deteriorate SNR and sampling error by a factor of 1.4; the square root of two. This is reduced to just 1.2 for a 12 interval gate; the square root of 1.5.

While these relationships provide ‘on the fly’ decision making for gating, they are equally valid when selecting other acquisition parameters. The choice of 30 versus 60 SPECT projections over 180 degrees, for example, would be informed with the knowledge that the 60 projections would result in (other factors being equal) a 1.4 fold (square root of two) deterioration in SNR and sampling error. Traditionally, under-sampling has been used in cardiac and brain SPECT because the small target can be positioned centrally in the axis of rotation, eliminating the deleterious effects the ‘star artifact’ associated with filtered backprojection. The marginal benefit in SNR and sampling error can be directly compared to potential risks associated with introduced artifact, particularly when the heart does not sit precisely in the centre of rotation. Similarly, changing from a 64 matrix to a 128 matrix would result in a two fold (square root of four) deterioration in SNR and sampling error. The inherent limitations in spatial resolution associated with imaging a moving (beating) structure for non gated SPECT obviated the need for larger pixel matrices. A 128 matrix may, however, be more appropriate for identifying small or non transmural myocardial defects on the end diastolic reconstructed slices. The marginal benefit of interpretive power can be readily compared to the associated decrease in image quality.

While these relationships are intuitive, particularly to the experienced practitioner, more precise calculation is warranted to appropriately inform decision making. This paper describes a very simple and intuitive method for determining and applying the physical principles that govern nuclear medicine.

References

1. Chua T, Kiat H, Maurer G, Germano G, Van Train K, Friedman J, Berman DS 1994, Gated technetium-99m sestamibi for simultaneous assessment of stress myocardial perfusion, post-exercise regional ventricular function and myocardial viability: Correlation with echocardiography and rest thallium-201 scintigraphy, J Am Coll Cardiol, vol. 23, pp. 1104-1111.
2. Narayanan M, King M, Wernick M, Byrne C, Soares E & Pretorius P 2000, Improved image quality and computation reduction in 4-D reconstruction of cardiac-gated SPECT images, IEEE, vol. 19, no. 5, pp. 423-433.
3. Bailey D & Parker J 1994, Single photon emission computerized tomography, in Nuclear medicine in clinical diagnosis and treatment, eds. IPC Murray & PJ Ell, vol. 2, Churchill Livingstone, Edinburgh, pp. 1315-1326.

Author Information

Geoffrey M Currie, M MedRadSc, M AppMngt, MBA, PhD
School of Dentistry and Health Sciences, Charles Sturt University, Wagga Wagga, Australia.

Janelle M Wheat, BAppSc, M MedRadSc, DHlthSc
School of Dentistry and Health Sciences, Charles Sturt University, Wagga Wagga, Australia.

Hosen Kiat, MBBS
School of Dentistry and Health Sciences, Charles Sturt University, Wagga Wagga, Australia.