Reconstruction Strategies for Gated Myocardial Perfusion SPECT: A Phantom Evaluation

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Foot line: Gated SPECT Reconstruction Strategies

ABSTRACT

The reconstruction strategy for gated myocardial perfusion SPECT can be stream-lined to reduce the computational demands of gated SPECT reconstruction, however, this may underestimate disease severity or increase false negative findings in the ungated qualitative image set.

Methods: A cardiac phantom with defect insert was acquired using 360 degree SPECT and reconstructed using two alternative methods. The first, method A, produced data for qualitative assessment of perfusion by first ungating the raw data and then reconstructing. The second, method B, produced data for qualitative assessment of perfusion by reconstructing the raw gated file and then ungating the slices. Defect extent and severity were determined using CEqual software. Spatial measures of reconstructed luminal, diameter, myocardial diameter, wall thickness and defect size were also recorded.

Results: The phantom results demonstrated that both the percentage extent of the defect and defect severity are reduced using method B compared to method A. Reconstruction using method B resulted in both an increase in total chamber diameter over method A and a reduction in the lumen diameter. Method B demonstrated a myocardial wall 20% thicker than method A. Method A was shown to underestimate the defect size by 5% while method B underestimates defect size by 30%.

Conclusion: Minimising the computational demands of gated SPECT processing using method B may lead to false negative results. This may be particularly troublesome for non transmural defects. An evaluation of the clinical impact of this error is warranted.

Key words:
phantom, myocardial perfusion, gated SPECT, reconstruction, filtering

INTRODUCTION

The computational demands for reconstruction of gated myocardial perfusion SPECT can be reduced. This may be a potential source of false negative findings in the ungated qualitative image set. While the cost of computer storage and power has decreased significantly in recent years, it may still play a role.[1]

There are a number of strategies employed for processing the gated and ungated data sets:

- The gated data set is summed to produce the ungated data set and each is independently reconstructed (Fig. 1; method A). This method is referred to in a number of texts[1,2] but results in increased processing time and storage requirements. This strategy is employed by 69% of Nuclear Medicine departments in Australia.[3]
- The gated data set is reconstructed to produce short axis, vertical long axis and horizontal long axis files whose intervals are subsequently summed to produce an ungated image data set (Fig. 1, method B). This strategy is employed by 31% of Nuclear Medicine departments in Australia.[3]

There are no guidelines or protocols published with systematic analysis that describe the appropriate strategy for gated SPECT reconstruction. It might seem intuitive that the gated dataset should be ungated prior to the filtering process for qualitative assessment of

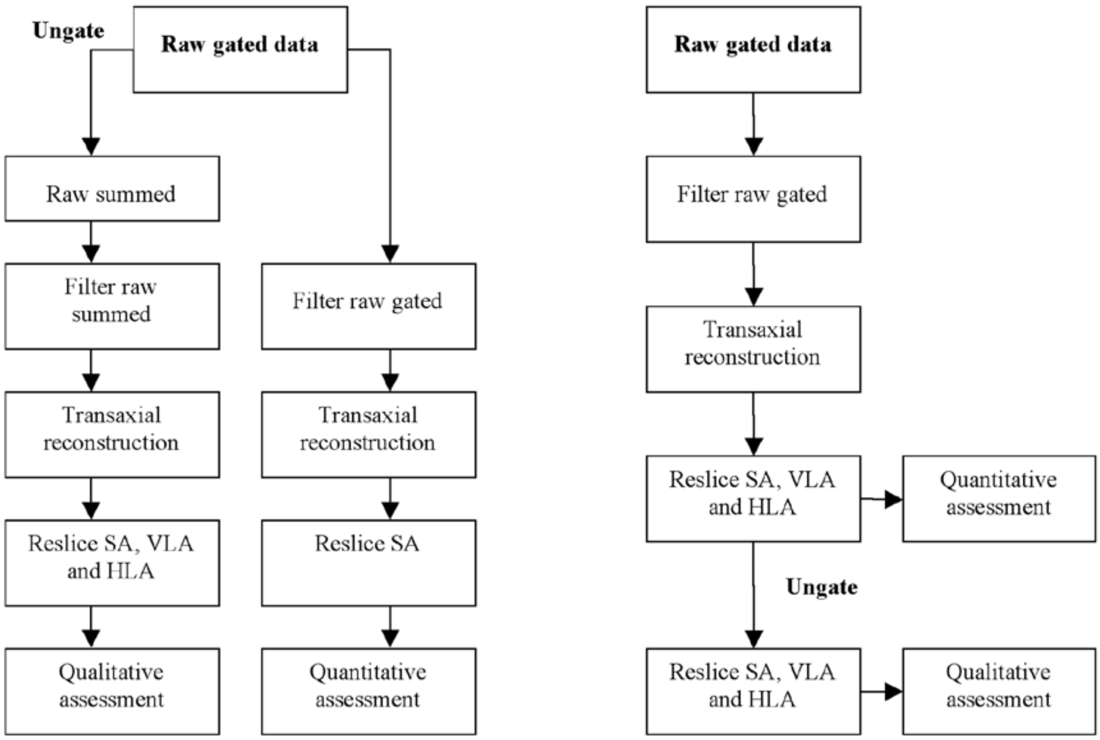

Figure 1: Processing algorithms for gated SPECT. Abbreviations include; short axis (SA), vertical long axis (VLA) and horizontal long axis (HLA). Reprinted with permission.[3]

perfusion to avoid displaying images that are the sum of eight (the number of gate intervals) separate filtering processes.

Methodology

A perspex cardiac phantom was contained within a perspex cylindrical chest phantom. The cylindrical chest phantom was 300 mm (width) x 225 mm (depth) x 190 mm (length) and contained 9.56 litres of water (excluding volume of cardiac insert) diluting 11.4 MBq of ^{99m}Tc pertechnetate to simulate lung background activity. Lung background activity was calculated as approximately 1.4% of a 740 MBq adult dose of ^{99m}Tc Sestamibi administered at stress and imaged one hour post administration.[4]

The cardiac phantom contained a cylindrical component representing the bulk of the heart and a spherical component representing the apex. This phantom permitted accurate modelling to the two part sampling method employed by CEqual quantitation. The short axis diameter of the inner chamber was 36 mm with a long axis length of 74 mm. The short axis diameter of the outer chamber was 60 mm with a long axis length of 86 mm. This configuration produced a left ventricular "myocardial wall" thickness of 12 mm. The actual normal left ventricular myocardial wall thickness ranges from 8 mm to 15 mm.[5] The chamber simulating the myocardial wall contained a volume of 120 ml prior to insertion of the perspex defect.

The cardiac phantom contained a perspex insert simulating a myocardial perfusion defect. The defect was a perspex wedge that produced a transmural defect whose dimensions represent the same relative defect area at both endocardial and pericardial defect boundaries. The defect was placed in the anterior wall toward the apex and was 20 mm x 15 mm at the pericardial side and 14 mm x 15 mm at the endocardial side.

The chamber simulating myocardial wall, after placement of the defect, was filled with 9.95 MBq of ^{99m}Tc pertechnetate diluted in 105 ml of water representing approximately 1.4% of the 740 MBq adult dose of 99mTc Sestamibi administered at stress and imaged one hour post administration.[4] The cardiac phantom chamber representing left ventricular lumen was filled with water but no radionuclide to represent the rapid blood clearance of ^{99m}Tc Sestamibi (90% clearance after five minutes) and the associated negligible blood activity at one hour post injection.[6]

The chest phantom was placed "supine" on the scanning table approximately in the centre of the gantry rotation. Within the chest phantom, the cardiac phantom was positioned with the long axis deviating 30º on the sagittal plane (apex towards left lateral) and 30º on the coronal plane (apex towards anterior). An eight interval gated SPECT study was acquired using a Philips Prism 1000 gamma camera with low energy high resolution collimation. The acquisition employed continuous mode with a circular orbit minimising radius of rotation (ROR). A 64 x 64 image matrix with a 1.5 magnification factor was combined with 6º angular sampling and a 32 second acquisition time per step over 360º.

The gated SPECT data for the phantom studies were reconstructed as both gated and ungated data sets to produce short axis slices. The two methods of reconstruction were performed simultaneously as a 'batch' to ensure identical reconstruction parameters and slice orientation. All phantom studies were reconstructed using 360º filtered backprojection. The following reconstruction procedure was applied to the control group (method A; Fig. 1):

- The gated data set was ungated to produce a conventional SPECT data set.

- The phantom study was pre-filtered with a Butterworth low pass filter (order 5.0 and cut-off 0.25 cycles/pixel).
- Reorientation of the transverse slices to accommodate cardiac orientation resulted in generation of short axis slices for CEqual quantitation.

The following reconstruction procedure was applied to the experimental group (method B; Fig. 1):

- All studies were pre-filtered with a Butterworth low pass filter (order 5.0 and cut-off 0.21 cycles/pixel).
- Reorientation of the transverse slices to accommodate cardiac orientation resulted in generation of short axis slices.
- Each set of three sets projection slices were then ungated.
- The short axis slices were then analysed using CEqual quantitation software.

The CEqual quantitative analysis software was used to evaluate and compare each control dataset with the experimental data set. For each short axis slice generated, the location, extent and severity of defects was recorded and compared for method A and method B. The percentage extent of the defects represented the percentage of pixels that fell below the normal limit threshold. The severity of each defect represented the summation of the values derived from multiplying each of the standard deviations below the normal range (i.e. one through eight) by the number of pixels which are calculated to be that number of standard deviations (SD) below the normal range.

Results

The phantom results demonstrated that both the percentage extent of the defect and defect severity are reduced using method B compared to method A. The extent of the defect decreased from 5% of the total myocardium using method A to 2% for method B. Similarly, defect severity improved from -127 SD to -60 SD. Spatial measures were taken of the chamber dimensions using a mid short axis slice and defect size using a mid vertical long axis slice (Table 1). Reconstruction using method B resulted in both an increase in total chamber diameter over method A and a reduction in the lumen diameter. While the overall chamber diameter closely approximates the actual dimensions, the luminal diameter for both reconstruction methods significantly underestimates the actual phantom diameters. Consequently, method A overestimates myocardial wall thickness by 45.8% and method B by 75%. Method A was shown to underestimate the defect size by 5% while method B underestimates defect size by 30%.

Table 1: Spatial measures in the phantom study

	Method A (mm)	Method B (mm)	Actual (mm)
Short axis luminal diameter	26	24	36
Short axis phantom diameter	61	66	60
Short axis wall thickness	17.5	21	12
Vertical long axis defect length	19	14	20
Defect extent	5%	2%	–
Defect severity	-127 SD	-60 SD	–

Discussion/Conclusion

Myocardial perfusion SPECT data reconstructed using method B results in a decrease in defect extent and severity, a decrease in left ventricular lumen diameter, an increase in total heart diameter and, thus, an increase in wall thickness. While method A provided a close approximation of actual defect size (5% underestimation), method B significantly underestimated defect size by 30%.

Minimising the computational demands of gated SPECT processing using method B may lead to false negative results, potentially eliminating small defects. This may be particularly troublesome for non transmural defects. In Australia, 59% of departments perform gating on the stress study only[7] and, thus, there is the potential to cause a normal finding in reversible ischaemia or reverse redistribution in infarction. Perfusion (ungated) and functional (gated) data should be processed independently.

An evaluation of the clinical impact of this error is warranted. An evaluation of the clinical impact of this error is. We suspect that the degradation of image resolution demonstrated in this study may compound the inherent 'blur' associated with imaging a moving structure in a clinical population. While gated SPECT improves resolution associated with the beating heart, this may not be true of the qualitative evaluation of the summed (ungated) data.

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