Gated Myocardial Perfusion SPECT In Australia

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Abstract

Introduction: Despite guidelines provided by the SNM and the ASNC, there is no universally accepted consensus on acquisition and processing protocols for gated myocardial perfusion SPECT. Anecdotal evidence suggests there is significant variability in both acquisition and processing parameters throughout Australian departments.

Methodology: This study was a self administered questionnaire of current acquisition and processing parameters utilised for gated myocardial perfusion SPECT across Australia. The sampling frame comprised 136 Nuclear Medicine departments across Australia including all departments accredited by the ANZSNM.

Results: With respect to the guidelines for performing gated myocardial perfusion SPECT outlined by the ASNC, only 4.4% (4/90) of Australian departments comply with minimum standards. The magnitude of this result, in a large part, is due to the high proportion of departments that do not gate both the rest and stress studies (68.9%). Exclusion of this parameter still means that just 13.3% (12/90) of Australian departments comply with minimum standards.

Conclusion: While the principle of gated myocardial perfusion SPECT is without debate there is a requirement for investigation and guidelines for optimisation of gated myocardial perfusion SPECT protocols. There is a need for further investigation of the actual impact of discordance with current guidelines on the diagnostic utility of gated myocardial perfusion SPECT.

INTRODUCTION

Each year in Australia, approximately 55000 myocardial perfusions studies are performed ([1]) because it is the key non invasive procedure that is in widespread use for the investigation of known or suspected CAD. In recent years there have been numerous advances in the technology, science and methodology utilised in performing myocardial perfusion studies in Nuclear Medicine. The emergence of ^{99m}Tc based radiopharmaceuticals combined with advances in technology have been responsible for the transition from planar imaging, to single photon emission computed tomography (SPECT) and more recently to gated SPECT.

For gated myocardial perfusion SPECT studies, imaging time is not increased (compared with ungated) and a traditional ungated image data set can be produced from the gated data set without compromising normal study quality. Processing time and memory required is, however, substantially increased (by a factor equal to the number of gate intervals) which means older computer systems may be inadequate for gated myocardial perfusion SPECT studies.

Despite guidelines provided by the Society of Nuclear Medicine (SNM) ([2]) and the American Society of Nuclear Cardiology (ASNC) ([3]), there is no universally accepted consensus on acquisition and processing protocols in gated myocardial perfusion SPECT. Anecdotal evidence suggests there is significant variability in both acquisition and processing parameters throughout Australian departments. This questionnaire aimed to outline current procedure and practice for gated myocardial perfusion SPECT in Australia and identify areas requiring further investigation.

METHODOLOGY

This study was a survey of current acquisition and processing parameters utilised for gated myocardial perfusion SPECT throughout Australia. The study design employed a self administered questionnaire, ensuring participant anonymity. The sampling frame included 136 Australian Nuclear Medicine departments. All departments accredited by the ANZSNM were included. A reply paid envelope was included for the return of the completed questionnaire.

The statistical significance was calculated using Chi square analysis for nominal data and Student's t test for continuous data. The F test analysis of variances was used to determine statistically significant differences within grouped data. A P value less than 0.05 was considered significant. The difference between independent means and proportions was calculated with a 95% confidence interval (CI).

RESULTS

The collection period saw 75 of the 136 questionnaires returned giving a minimum compliance rate of 56.0% (75/134). The 75 questionnaires represented the practices of 101 individual departments and, therefore, it is possible that compliance was as high as 75.4% (101/134). Responder compliance of between 56.0% to 75.4% for a self administered postal questionnaire was considered an excellent response.

The stress study only is gated for 64.4% (58/90) of departments (95% CI: 54.2% to 73.6%). The rest study only is gated in 4.4% (4/90) of departments (95% CI: 1.7% to 10.9%) and both stress and rest studies are gated in 31.1% (28/90) of departments. An eight interval gated SPECT was the method of choice in 91.0% of departments (Table 1).

Figure 1

Table 1: Distribution of interval number in gated myocardial perfusion SPECT.

Gate Intervals	% of Departments	Number of 89	95% CI of %
8	91.0	81	83.3 – 95.4
12	1.1	1	0.2 – 6.1
16	5.6	5	2.4 – 12.5
18	2.2	2	0.6 – 7.8

DATA ACQUISITION

A fixed window width is the strategy employed for 'bad beat' rejection in 47.7% (42/88) of departments (95% CI: 37.6% to 58.0%). Abandoning gating is the strategy employed for dealing with 'bad beats' in 22.7% (20/88) of departments (95% CI: 15.2% to 32.5%). A rejected beats bin is the strategy employed for dealing with 'bad beats' in 21.6% (19/88) of departments (95% CI: 14.3% to 31.3%). A further 8.0% (7/88) of departments use a combination of both a fixed window and abandoning gating where necessary.

^{201}Tl thallous chloride is the radiopharmaceutical of choice for gated stress studies in 13.3% (12/90) of departments (95% CI: 7.8% to 21.9%). Of the remaining departments, 82.2% (74/90) use ^{99m}Tc based radiopharmaceuticals for stress studies and 4.4% (4/90) employ a mix of both ^{201}Tl and ^{99m}Tc (Table 2). ^{201}Tl thallous chloride is the radiopharmaceutical of choice for gated rest studies in 23.3% (21/90) of departments (95% CI: 15.8% to 33.1%). Of the remaining departments, 72.2% (65/90) use ^{99m}Tc based radiopharmaceuticals for rest studies and 4.4% (4/90) employ a mix of both ^{201}Tl and ^{99m}Tc (Table 2). Table 3 summarises the rest/stress radiopharmaceutical use.

Figure 2

Table 2: Department use of radiopharmaceuticals for stress and rest myocardial perfusion SPECT.

	STRESS		REST	
R/P	%	95% CI	%	95% CI
^{201}Tl	13.3 (12/90)	7.8 - 21.9	23.3 (21/90)	15.8 - 33.1
^{201}Tl & ^{99m}Tc	4.4 (4/90)	1.7 - 10.9	4.4 (4/90)	1.7 - 10.9
Sestamibi	41.1 (37/90)	31.5 - 51.4	33.3 (30/90)	24.5 - 43.6
Tetrofosmin	30.0 (27/90)	21.5 - 40.1	27.8 (25/90)	19.6 - 37.8
MIBI & MYO	11.1 (10/90)	6.1 - 19.3	11.1 (10/90)	6.1 - 19.3

Figure 3

Table 3: Stress and rest radiopharmaceutical combinations.

STRESS	REST	%
Sestamibi	Sestamibi	33.3 (30/90)
Myoview	Myoview	27.8 (25/90)
MIBI/MYO	MIBI/MYO	11.1 (10/90)
MIBI/Thal	MIBI/Thal	4.4 (4/90)
Thallium	Sestamibi	7.8 (7/90)
Thallium	Myoview	2.2 (2/90)
Thallium	Thallium	13.3 (12/90)

Variable detector gantry configurations are employed for gated myocardial perfusion SPECT in 52.2% (47/90) of departments (95% CI: 42.0% to 62.2%). Triple detector gantries are employed in 14.4% (13/90) of departments (95% CI: 8.6% to 23.3%), fixed dual opposed gantries in 6.7% (6/90) of departments (95% CI: 3.1% to 13.8%) while 16.7% (15/90) of departments employ single detector gantries. Multiple types of gantry configurations were employed for gated myocardial perfusion SPECT in 10.0% (10/90) of departments.

The acquisition matrix employed for gated myocardial perfusion SPECT was 64x64 for 79.5% (70/88) of departments (95% CI: 70.0% to 86.6%). No overlap of confidence intervals indicates a statistically significant higher representation of 64x64 matrix than the 20.5% (18/88) employing 128x128 matrix (95% CI: 13.3% to 30.0%). Comparison with departments indicating that gating was not performed on myocardial perfusion SPECT indicated that these departments are 2.1 times more likely (relative risk) to use a 128x128 matrix than departments employing gating The use of ^{201}Tl is 1.2 times more likely

(RR) to see the employment of a 64x64 matrix than ^{99m}Tc studies in gated myocardial perfusion SPECT.

SPECT angular sampling for gated myocardial perfusion SPECT was 3° in 63.9% (53/83) of departments (95% CI: 53.1% to 73.4%). No overlap of confidence intervals indicates a statistically significant higher representation of 3° angular sampling than the 18.1% (15/83) employing 6° angular sampling (95% CI: 11.3% to 27.7%). Other angular sampling employed include 12.0% (10/88) of departments using 4°, 4.8% (4/88) using 5° and 1.2% (1/88) using 2°. A statistically significant difference was detected for angular sampling between gate intervals (P = 0.001) with 100% (5/5) of departments employing 16 interval gating also employing a 6° angular sampling. The use of a 6° angular sampling was also 3.0 times more likely (RR) employing ^{201}Tl than ^{99m}Tc. An acquisition matrix of 64x64 is 5.1 times more likely (RR) than 128x128 matrix for 3° angular sampling.

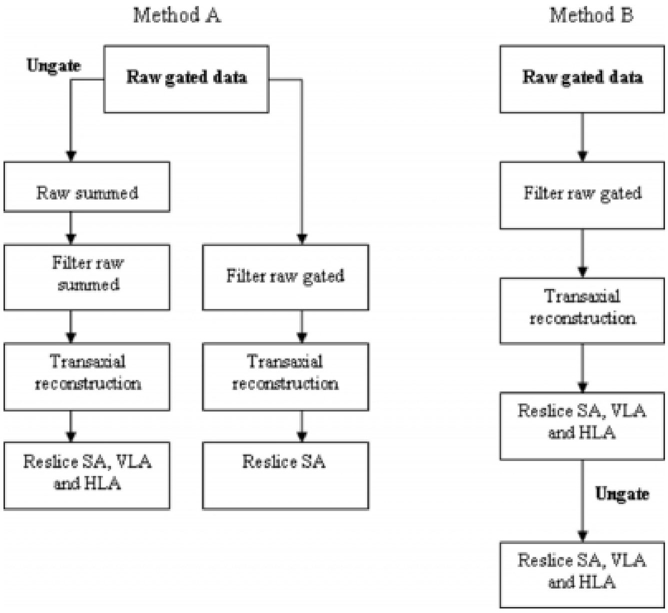
All departments (90/90) routinely assess the gated myocardial perfusion SPECT data for patient motion. This may provide evidence of obsequiousness bias due to an obvious 'worst practice' response. The cinematic display of the raw data is used by 53.3% (48/90) of departments to evaluate gated studies for motion (95% CI: 43.1% to 63.3%) while 7.8% (7/90) use the sinogram of the raw data for this assessment (95% CI: 3.8% to 15.2%). Both the sinogram and cinematic display are employed by 38.9% (35/90) of departments to evaluate the presence of patient motion in gated myocardial perfusion SPECT (95% CI: 29.5% to 49.2%).

RECONSTRUCTION

The reconstruction strategy depicted by method A in Figure 1 was employed by 68.9% (62/90) of departments (95% CI: 58.7% to 77.5%). Method B (Fig. 1) was employed by 31.1% (28/90) of departments (95% CI: 22.5% to 41.3%). Filtered backprojection is the reconstruction algorithm of choice for gated myocardial perfusion SPECT in 73.3% (66/90) of departments (95% CI: 63.4% to 81.4%). Iterative reconstruction is employed as the reconstruction algorithm of choice in 14.4% (13/90) of departments (95% CI: 8.6% to 23.2%). A further 12.2% (11/90) of departments indicate that both iterative and filtered backprojection algorithms are employed for gated myocardial perfusion SPECT (95% CI: 7.0% to 20.6%).

Figure 4

Figure 1: Processing algorithms for gated SPECT. Adapted from Germano & Berman (4).



Reconstruction of gated myocardial perfusion SPECT is performed using 180° of data in 82.2% (74/90) of departments (95% CI: 73.1 to 88.8%) while 360° of data is reconstructed in 5.6% (5/90) of departments (95% CI: 2.4% to 12.4%). A further 7.8% (7/90) of departments indicate that both 180° and 360° of data is reconstructed (95% CI: 3.8% to 15.2%) and 4.4% (4/90) use other angular configurations (240° and 270°).

Pre filtering is employed in the reconstruction process for gated myocardial perfusion SPECT in 58.0% (51/88) of departments (95% CI: 47.5% to 67.7%) while a post filter is employed in 39.8% (35/88) of departments (95% CI: 30.2% to 50.2%). A further 2.2% (2/88) of departments indicate that both pre and post filters are employed (95% CI: 0.6% to 7.9%). Pre filtering is 1.6 times more likely (RR) than post filtering in departments using ^{201}Tl for gated SPECT.

Attenuation correction is employed for gated myocardial perfusion SPECT in 12.1% (11/90) of departments, of which 54.5% (6/11) use a transmission method (95% CI: 3.1% to 13.8%) and 45.5% (5/11) use an estimation method (95% CI: 2.4% to 12.4%). The remaining 87.7% (79/90) of departments do not employ attenuation correction for gated myocardial perfusion SPECT (95% CI: 79.4% to 93.0%). The use of ^{99m}Tc based radiopharmaceuticals by departments is associated with a 2.7 times greater likelihood (RR) than departments using ^{201}Tl to perform attenuation correction.

QGS is the quantitative software of choice in 58.9% (53/90) of departments (95% CI: 48.6% to 68.5%). ECTb is the quantitative software of choice in 20.0% (18/90) of departments (95% CI: 13.0% to 29.4%). A further 10.0% (9/90) of departments indicated that both QGS and ECTb are employed (95% CI: 5.4% to 17.9%) and 11.1% (10/90) employ other quantitative software (95% CI: 6.1% to 19.2%).

DISCUSSION

With respect to the guidelines for performing gated myocardial perfusion SPECT outlined by the ASNC (3), only 4.4% (4/90) of Australian nuclear medicine departments comply with minimum standards (Table 4). The magnitude of this result, in a large part, is due to the high proportion of departments that do not gate both the rest and stress studies (68.9%). Exclusion of this parameter still means that just 13.3% (12/90) of Australian nuclear medicine departments comply with minimum standards. Inclusion of the use of method B (Fig. 1) and / or pre-filtering as discordant leaves just 2.2% (2/90) of departments comply with recommendations for performing gated myocardial perfusion SPECT.

Figure 5

Table 4: Summary of discordance of Australian practice and recommended parameters of the ASNC (3). It is worth noting that the importance of some parameters may be dependant on others. For example, the impact of a 128x128 matrix on count density is substantially higher if the SPECT 16 gate intervals.

	ASNC (*3*)	**% Discordant**
Gantry	Variable or triple	33.4
Gating	Yes	9.1
Studies gated	Rest & stress	68.9
Gate intervals	8	9.0
Matrix	64x64	20.5
Angular sampling	3-6 degrees	1.2
Bad beat rejection	100% window	0
Patient motion	Cine and/or sino	0
Sub total discordance		**95.6%**
Use of method B		31.1
Pre-filter with QGS		36.4
Total discordance		**97.8%**

A 64x64 acquisition matrix is recommended for gated SPECT by the ASNC (3) because the benefits of a 128x128 matrix in terms of image quality are insufficient to offset the additional storage space required and processing time. One might conclude, however, that a four fold decrease in counts per pixel in studies with counts per pixel already decreased by a factor approximately equal (depending on rejected beats) to the number of gate intervals might be a more important consideration. The vast majority of departments in Australia (79.5%) employ a 64x64 matrix for gated myocardial perfusion SPECT.

It was interesting to note that 100% of departments indicated that the cinematic display and/or the sinogram of the raw data are evaluated for patient motion. This may be the result of reconstruction macros including a step where the cinematic display and sinogram are displayed. This may not translate to the studies actually being evaluated adequately (or corrected) for patient motion. Perhaps another cause of this result is obsequiousness bias since the question offers an obvious 'worst practice' alternative. This result is certainly counter intuitive to anecdotal evidence. More importantly, the 31.1% of departments employing method B (Fig. 1) as a reconstruction strategy may find it difficult to confirm the presence of patient motion on the low count gated sinogram and/or cinematic display. Furthermore, the integrity of any attempt to correct patient motion may be compromised in the gated data compared to the ungated data.

It is universally recommended that default filter parameters are adhered to due to the danger of introducing false positive or false negative results following filter customisation (5). Over filtering myocardial perfusion SPECT data is known to cause false negative results and under filtering causes false positive results (5). Despite QGS quantitation prescribing a post filter, 36.4% (32/88) of departments employ a pre filter with QGS software. It is worth noting that a current unpublished investigation by these authors found that the mean ejection fraction determined using a pre filter was 4.98% higher than the post filtered mean ($P < 0.0001$).

The reconstruction strategy employed may be stream-lined to reduce the computational demands of gated SPECT reconstruction and, thus, may be a potential source of false negative findings in the ungated qualitative image set. 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 is the method loosely referred to in a number of texts (4,8) but results in increased processing time and storage requirements.
- 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 method may be used to save processing time.

A major limitation of reconstruction filters in SPECT is that optimal filters for qualitative or visual evaluation may be quite different from optimal filters for quantitation. The most appropriate filter for gated data may be quite different from that of the ungated data since the ungated data has 8 times (assuming 8 interval gated acquisition) more counts per pixel than the gated data. There are no guidelines or protocols published that describe the appropriate strategy for gated SPECT reconstruction. Intuitively, the gated dataset should be ungated prior to the filtering process to generate the traditional image dataset to avoid displaying images that have been filtered 8 times (the number of gate intervals). The over filtering of perfusion data using method B (Fig. 1) may lead to false negative studies. While Germano & Berman ([4]) and DePuey ([8]) have published flow charts suggesting the use of method A (Fig. 1), there is no discussion in the literature supporting this proposition.

The most important results of this study relate to which studies are gated in the myocardial perfusion SPECT. The majority of departments (64.4%) only perform gating on the stress study. The ASNC ([3]) recommends gating be performed on both rest and stress studies due to differences between the rest and post stress functional parameters. While the perfusion study represents perfusion at the time of injection, the functional information represents function at the time of imaging. Despite the stress study being acquired at rest, the cardiac function may be impacted by stress induced stunning. Comparing both rest and stress functional data can offer both diagnostic and prognostic value to the procedure. Only 31.1% of departments gate both the rest and stress studies. Perhaps the crucial observation is that 26.6% (24/90) of departments employ method B (Fig. 1) while only performing gated SPECT on one of the studies. Thus, over filtering is only problematic in the study that was gated. While this re-introduces the 'apples and oranges' interpretation scenario, the potential impact on diagnostic utility is more important. If the gated study was the stress study, over filtering could potentially obscure small areas of ischaemia producing a false negative finding. Similarly, the gated rest study might obscure a small infarct leading to a diagnosis of reversible ischaemia.

While the majority of departments (91.0%) employ 8 interval gating, strategies for dealing with 'bad beats' are a little more varied. Of course, an 8 interval gate, compared to 16 for instance, not only improves counts per pixel but also reduces the deleterious impact of variations in heart rate. It is crucial that, despite the advantages of the functional information provided by gated SPECT, the perfusion data should not be compromised. Consequently, to maintain the integrity of the functional information, all data rejected should be collected in an additional (9th) bin to include in the reconstruction of the perfusion data. Only 21.6% (19/88) of Australian departments employ an additional rejected beats bin, however, another 30.7% (27/88) abandon gating if the perfusion data is compromised. While the ASNC ([3]) recommends a 100% window so the functional information is not acquired at the expense of the perfusion data, Paul and Nabi ([6]) recommend a 20% acceptance window and DePuey ([5]) indicated that 25% to 35% is typical in clinical practice. Interestingly, Nichols et al. ([7]) reported that only 26% of 379 gated myocardial perfusion SPECT patients had data sets free of gating errors.

CONCLUSION

The benefits of the added functional information provided by gated SPECT of myocardial perfusion studies are universally accepted ([4,5]), however, there are a number of criteria which need to accompany gated SPECT ([4]):

- Minimal increase in cost and inconvenience of performing gated SPECT.
- Primum non nocere, above all, do not make the patient worse. The perfusion data integrity should not be compromised by the functional data.

The former is an established advantage of performing gated myocardial perfusion SPECT, however, there is potential for the latter due to sources of error that may decrease diagnostic integrity. In light of the results of this survey, one ponders whether the ASNC guidelines for gated myocardial perfusion SPECT are universally appropriate? If they are, is gated myocardial perfusion SPECT sufficiently robust to changes in acquisition and processing parameters that diagnostic integrity is not compromised? While the principle of gated myocardial perfusion SPECT is without debate, there is a requirement for investigation and guidelines for optimisation of gated SPECT protocols. There is a need for further investigation of the actual impact of discordance with current guidelines on the diagnostic utility of gated myocardial perfusion SPECT.

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