Myocardial Perfusion SPECT in Australia: Acquisition Parameters

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ABSTRACT
Introduction: Despite clear guidelines provided by the Society of Nuclear Medicine (SNM) and the American Society of Nuclear Cardiology (ASNC), there is no universally accepted consensus on acquisition protocols for myocardial perfusion SPECT.

Methodology: This study was a self administered, anonymous questionnaire of current acquisition procedures employed for myocardial perfusion SPECT across Australia. The sampling frame comprised 136 Nuclear Medicine departments across Australia including all departments accredited by the Australia and New Zealand Society of Nuclear Medicine (ANZSNM).

Results: With respect to the recommended acquisition parameters outlined by both the SNM and the ASNC, only 14.9% (15/101) of Australian nuclear medicine departments comply with minimum standards. This translates to 17.4% (235/1351) of studies performed weekly in Australia. The stress study only is gated for 58.6% (58/99) of departments (95% CI: 44.6% to 73.7%) while no gating is performed in 9.1% (9/99) of departments (95% CI: 4.9% to 16.4%). The rest study only is gated in 4.0% (4/99) of departments and both stress and rest studies are gated in 28.3% (28/99) of departments.

Conclusion: While the principle of gated myocardial perfusion SPECT is without debate there is a requirement for investigation and guidelines for optimisation of acquisition protocols.

Key words: myocardial perfusion SPECT, acquisition procedure, consensus
acquisition protocols in myocardial perfusion SPECT. Anecdotal evidence suggests there is significant variability in acquisition protocols throughout Australian departments. This questionnaire aims to outline current procedure and practice for myocardial perfusion SPECT in Australia.

METHODOLOGY
This study was a survey of current acquisition procedures employed for myocardial perfusion SPECT in Australia. The study design utilised a self administered questionnaire to provide participant confidentiality. A structured questionnaire was employed in order to collect unambiguous answers for quantitative evaluation.

In August 2004, 136 questionnaires were sent to the Chief Technologists of each Nuclear Medicine department in the sampling frame. The sampling frame included all Australian departments accredited by the ANZSNM in addition to those departments identified under a “nuclear medicine” search query of the online telephone directory. 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 variance 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 per cent confidence interval (CI). Relative risk (RR) was used to determine the strength of association between exposure and outcomes.

RESULTS
At the completion of the four week data collection period 75 of the 136 questionnaires had been returned completed. Another two questionnaires were returned unopened with a postal notation that the addressee was unknown. Thus, a minimum compliance rate of 56.0% (75/134) was determined. The 75 questionnaires represented the practices of 101 individual departments and, therefore, it is possible that compliance was as high as 75.4 per cent (101/134). Responder compliance of between 56.0 per cent to 75.4 per cent for a self administered postal questionnaire was considered an excellent response.

Demographic Data
Department demographics included 31.7 per cent (32/101) public hospitals, 28.7 per cent (39/101) private hospitals and 39.6 per cent (40/101) private clinics. The mean number of myocardial perfusion SPECT studies performed weekly was 13.5 per department with a range of 0 to 45 (95 per cent Cl: 11.6 to 15.4). The mean number of studies performed weekly in public hospitals was 18.0 (95 per cent Cl: 14.2 to 21.8) with a range of 0 to 45. The mean number of studies performed annually in private hospitals was 11.8 (95 per cent Cl: 8.5 to 15.1) with a range of 2 to 35. The mean number of studies performed weekly in private clinics was 11.1 (95 per cent Cl: 8.3 to 13.9) with a range of 0 to 40. Lack of overlap of 95 per cent CI support a statistically significant difference in the mean number of studies performed in public hospitals compared to private clinics.

Table 1: Department use of radiopharmaceuticals for stress and rest myocardial perfusion SPECT.

<table>
<thead>
<tr>
<th></th>
<th>R/P</th>
<th>R/P</th>
</tr>
</thead>
<tbody>
<tr>
<td>R/P</td>
<td>per cent</td>
<td>per cent</td>
</tr>
<tr>
<td><strong>Tl</strong></td>
<td>16.1 [16/99]</td>
<td>95 per cent CI 10.2-24.7</td>
</tr>
<tr>
<td>Both</td>
<td>4.4 [4/99]</td>
<td>Both 4.4 [4/99]</td>
</tr>
<tr>
<td><strong>Tc</strong></td>
<td>79.8 [79/99]</td>
<td><strong>Tc</strong> 70.7 [70/99]</td>
</tr>
<tr>
<td>Sestamibi</td>
<td>49.4 [39/79]</td>
<td>Sestamibi 45.7 [32/70]</td>
</tr>
<tr>
<td>Tetrofosmin</td>
<td>38.0 [30/79]</td>
<td>Tetrofosmin 40.0 [28/70]</td>
</tr>
<tr>
<td>Both</td>
<td>12.6 [10/79]</td>
<td>Both 14.3 [10/70]</td>
</tr>
</tbody>
</table>

Radiochemicals
**Tl** thallous chloride is the radiopharmaceutical of choice for stress studies in 16.1 per cent (16/99) of departments (95 per cent Cl: 10.2 per cent to 24.7 per cent). Of the remaining departments, 79.8 per cent (79/99) use **Tc** based radiopharmaceuticals for stress studies and 4.4 per cent (4/99) employ a mix of both **Tl** and **Tc** (Table 1). Stress radiopharmaceuticals can be further stratified with 49.4 per cent (39/79) of departments using **Tc** radiopharmaceuticals employing Sestamibi, 38.0 per cent (30/79) Tetrofosmin and 12.6 per cent (10/79) a combination of both Sestamibi and Tetrofosmin. **Tl** thallous chloride is the radiopharmaceutical of choice for rest studies in 25.3 per cent (25/99) of departments (95 per cent Cl: 17.7 per cent to 34.6 per cent). Of the remaining departments, 70.7 per cent (70/99) use **Tc** based radiopharmaceuticals for rest studies and 4.4 per cent (4/99) employ a mix of both **Tl** and **Tc** (Table 1). Rest radiopharmaceuticals can be further stratified with 54.7 per cent (32/70) of departments using **Tc** radiopharmaceuticals employing Sestamibi, 40.0 per cent (28/70) Tetrofosmin and 14.3 per cent (10/70) a combination of both Sestamibi and Tetrofosmin.

**Tl** thallous chloride stress and rest / redistribution procedures are employed in 16 departments while nine employ a **Tc** based stress and **Tl** rest study. Excluding these nine **Tc** based stress studies, all stress studies employed the same radiopharmaceutical as employed for the rest study.
No statistically significant relationship was demonstrated between the mean full time equivalent technologists (department size) and the stress radiopharmaceutical employed (P = 0.16) or the rest radiopharmaceutical (P = 0.28). No statistically significant relationship was demonstrated between the mean number of studies performed weekly in the department and the stress radiopharmaceutical employed (P = 0.15). A statistically significant relationship was, however, demonstrated between the mean number of studies performed in departments employing 201Tl thallous chloride as the rest radiopharmaceutical (17.9) compared to 99mTc based rest radiopharmaceuticals (10.7) (P = 0.006). A trend was also noted between department type and radiopharmaceutical employed with private departments being 2.1 times more likely (RR) than public departments to employ Tetrofosmin. Furthermore, public departments were 1.5 times more likely to employ 201Tl thallous chloride than private departments.

Gantry Configuration
Variable detector gantry configurations are employed for myocardial perfusion SPECT in 59.6 per cent (59/99) of departments (95 per cent CI: 40.8 per cent to 60.1 per cent). Triple detector ga ntries are employed in 22.2 per cent (22/99) of departments, fixed dual opposed ga ntries in 7.1 per cent (7/99) of departments while 21.2 per cent (21/99) of departments employ single detector gantries. Multiple types of gantry configurations were employed for myocardial perfusion SPECT in 10.1 per cent (10/99) of departments.

A single detector gantry is 3.7 times more likely to be employed for myocardial perfusion SPECT in a private clinic than a public hospital (RR) and 4.0 times more likely in a private clinic than private hospital. A statistically significant difference was noted for the mean number of studies performed weekly between gantry types (P = 0.007). Most notably, the statistically significant differences were noted for the mean number of studies performed weekly for departments employing single detector ga ntries for myocardial perfusion SPECT (7.7) and those employing triple detectors (17.4) (P = 0.004) and variable detectors (15.9) (P < 0.001).

A statistically significant difference was noted for the mean number of full time equivalent technologists between gantry types (P < 0.001). Statistically significant differences were noted for the mean number of full time equivalent technologists for departments employing single detector ga ntries for myocardial perfusion SPECT (2.0) and those employing triple detectors (5.5) (P < 0.001) and variable detectors (3.4) (P = 0.02). Statistically significant differences were noted for the mean number of full time equivalent technologists for departments employing dual opposed detector ga ntries for myocardial perfusion SPECT (1.5) and those employing triple detectors (5.5) (P < 0.001) and variable detectors (3.4) (P = 0.048). Statistically significant differences were also noted for the mean number of full time equivalent technologists for departments employing triple detectors for myocardial perfusion SPECT (3.5) and those employing variable detectors (3.4) (P = 0.003).

A variable detector gantry is employed for stress studies in 75 per cent (12/16) of departments utilizing 201Tl thallous chloride. 201Tl thallous chloride is 2.5 times more likely to be employed in departments employing a variable detector gantry (RR). Furthermore, 100 per cent (99) of 99mTc stress / 201Tl rest studies were performed in departments employing a variable detector gantry.

Gated Acquisition
The stress study only is gated for 58.6 per cent (58/99) of departments (95 per cent CI: 44.6 per cent to 73.7 per cent) while no gating is performed in 9.1 per cent (9/99) of departments (95 per cent CI: 4.9 per cent to 16.4 per cent). The rest study only is gated in 4.0 per cent (4/99) of departments and both stress and rest studies are gated in 28.3 per cent (28/99) of departments. No statistically significant difference was noted between studies gated and department type (P = 0.09), mean number of full time equivalent technologists (P = 0.96) or the mean number of studies performed weekly (P = 0.34). Not surprisingly, 44.4 per cent (4/9) of departments not gating myocardial perfusion SPECT employ 201Tl thallous chloride as the radiopharmaceutical of choice and, thus, departments not employing gating are 3.3 times more likely (RR) to use 201Tl thallous chloride than 99mTc based radiopharmaceuticals. Single detector ga ntries are employed for myocardial perfusion SPECT in 55.6 per cent (59/99) of departments not utilising gating and, thus, departments not employing gating are 4.3 times more likely (RR) to employ a single detector gantry than multiple detector configurations.

The number of gate intervals employed was 8 for 91.0 per cent (81/89) of departments performing gated studies (95 per cent CI: 83.3 per cent to 95.4 per cent). No overlap of confidence intervals indicates a statistically significant higher representation of 8 interval gated studies than the 6 per cent (5/89) employing 16 intervals (95 per cent CI: 2.4 per cent to 12.5 per cent). A further 1.1 per cent (1/89) use 12 interval gating and 2.2 per cent (2/89) employ 18 interval gating.

A fixed window width is the strategy employed for "bad beat" rejection in 49.5 per cent (45/91) of departments (95 per cent CI: 39.4 per cent to 59.5 per cent). Abandoning gating is the strategy employed for dealing with "bad beats" in 22.0 per cent (20/91) of departments (95 per cent CI: 14.7 per cent to 31.5 per cent). A rejected beats bin is the strategy employed for dealing with "bad beats" in 20.9 per cent (19/91) of departments (95 per cent CI: 13.8 per cent to 30.3 per cent). A further 7.7 per cent (7/91) of departments use a combination of both a fixed window and abandoning gating where necessary. No overlap of confidence intervals with the fixed window strategy indicates a statistically significant higher representation of this strategy over other strategies. A "bad beat" rejection bin was 4.2 times more likely (RR) to be employed in departments using attenuation correction than those not using attenuation correction.

Acquisition Matrix
The acquisition matrix employed was 64x64 for 78.1 per cent (75/96) of departments (95 per cent CI: 68.9 per cent to 85.2 per cent). No overlap of confidence intervals indicates a statistically significant higher representation of 64x64 matrix than the 21.9 per cent (21/96) employing 128x128 matrix (95 per cent CI: 14.6 per cent to 31.1 per cent). No other matrix sizes were employed. A
128x128 matrix was 2.5 times more likely (RR) to originate from a private hospital department than other department types. Departments not gating myocardial perfusion SPECT are 2.1 times more likely (RR) to use a 128x128 matrix than departments employing gating and the use of 201TI is 1.2 times more likely (RR) to see the employment of a 64x64 matrix than 99mTc studies.

SPECT Angular Sampling
SPECT angular sampling was 3° in 62.6 per cent (57/91) of departments (95 per cent CI: 52.4 per cent to 71.9 per cent). No overlap of confidence intervals indicates a statistically significant higher representation of 3° angular sampling than the 17.6 per cent (16/91) employing 6° angular sampling (95 per cent CI: 11.1 per cent to 26.7 per cent). Other angular sampling employed include 14.3 per cent (13/91) of departments using 4°, 4.4 per cent (4/91) using 5° and 1.1 per cent (1/91) using 2°. A statistically significant difference was detected for angular sampling between gate intervals (P = 0.001) with 100 per cent (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 201TI than 99mTc. An acquisition matrix of 64x64 is 5.1 times more likely (RR) than 128x128 matrix for 3° angular sampling while 6° angular sampling is 2.8 times more likely (RR) to be employed in studies using 128x128 matrix rather than 64x64.

Attenuation Correction
Attenuation correction is employed in 14.1 per cent (14/99) of departments, of which 50 per cent (7/14) use a transmission method (95 per cent CI: 34.3 per cent to 18.9 per cent) and 50 per cent (7/14) use an estimation method (95 per cent CI: 3.4 per cent to 13.9 per cent). No overlap of confidence intervals indicates a statistically significant lower representation of attenuation use than the 85.9 per cent (85/99) of departments that do not employ attenuation correction (95 per cent CI: 77.7 per cent to 91.4 per cent). Attenuation correction was 2.1 times more likely (RR) to be performed in public hospitals than the private sector. The use of 99mTc based radiopharmaceuticals by departments is associated with a 2.7 times greater likelihood (RR) than departments using 201TI to perform attenuation correction.

Patient Motion
All departments (99/99) routinely assess the 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 53.5 per cent (53/99) of departments to evaluate studies for motion while 10.1 per cent (10/99) use the sinogram of the raw data for this assessment. Both the sinogram and cinematic display are employed by 36.4 per cent (36/99) of departments to evaluate the presence of patient motion.

SUMMARY
With respect to the recommended acquisition parameters outlined by both the SNM and the ASNC, only 14.9 per cent (15/101) of Australian nuclear medicine departments comply with minimum standards (Table 2). This translates to 17.4 per cent (235/1351) of studies performed weekly in Australia. The slightly higher proportion of concordant studies performed compared to departments reflects the higher mean number of studies performed weekly in departments demonstrating concordance with these guidelines (16.8) compared to those discordant (13.0) (P = 0.0005). That is to say, busier departments tend to be more compliant with recommended acquisition procedures. Similarly, larger departments are also more compliant with the guidelines which is indicated by the higher mean number of full time equivalent technologists in concordant departments (4.0) compared to discordant departments (3.1) (P = 0.001).

The magnitude of the results outlined above are, in a large part, due to the high proportion of departments that do not gate both the rest and stress studies (71.7 per cent). If this parameter is limited just to those departments that do not perform gating at all (9.1 per cent) one notes that 50.5 per cent (51/101) of Australian nuclear medicine departments comply with minimum standards. This translates to 61.9 per cent (836/1351) of studies performed weekly in Australia.

Table 2: Summary of discordance of Australian practice and recommended parameters of the SNM and ASNC. 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 reduced if studies that are not gated.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SNM</th>
<th>ASNC</th>
<th>per cent Discordant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiopharmaceutical</td>
<td>99mTc (mibi / myo) or 201TI</td>
<td>99mTc (mibi / myo) or 201TI</td>
<td>0</td>
</tr>
<tr>
<td>Gantry</td>
<td>-</td>
<td>Variable or triple</td>
<td>18.2</td>
</tr>
<tr>
<td>Gating</td>
<td>Yes</td>
<td>Yes</td>
<td>9.1</td>
</tr>
<tr>
<td>Studies gated</td>
<td>-</td>
<td>Rest &amp; stress</td>
<td>71.7</td>
</tr>
<tr>
<td>Gate intervals</td>
<td>-</td>
<td>8</td>
<td>9.0</td>
</tr>
<tr>
<td>Matrix</td>
<td>-</td>
<td>64x64</td>
<td>21.9</td>
</tr>
<tr>
<td>Angular sampling</td>
<td>3-6 degrees</td>
<td>3-6 degrees</td>
<td>1.1</td>
</tr>
<tr>
<td>Bad beat rejection</td>
<td>-</td>
<td>100 per cent window</td>
<td>-</td>
</tr>
<tr>
<td>Attenuation correction</td>
<td>Optional</td>
<td>Optional</td>
<td>-</td>
</tr>
<tr>
<td>Patient motion</td>
<td>Yes</td>
<td>Cine and/or sino</td>
<td>0 per cent</td>
</tr>
</tbody>
</table>

Australian departments discordant with overall ASNC guidelines | 85.1 per cent (86/101) |

Patients studies performed in Australia discordant with overall ASNC recommendations | 82.6 per cent (1116/1351) |
DISCUSSION

Compliance of individual departments was between 56.0 per cent (75/134) and 75.4 per cent (101/134) because some respondents indicated that the returned questionnaire represented multiple departments. While public hospitals represented 31.7 per cent (32/101) of respondents, they only represented 22.4 per cent (30/134) of the initial sampling frame. This observation may indicate volunteer bias associated with a greater interest from public hospitals. This is supported by the higher mean number of studies performed weekly in public hospitals (18) compared to private hospitals (11.8) and private clinics (11.1).

It was interesting to note that busier departments had a greater tendency to employ $^{99m}$Tc thallous chloride as the radiopharmaceutical of choice. From the data it is not possible to determine the cause of such a relationship, however, it may be due to economic factors, for example, a threshold may exist over or under which one radiopharmaceutical is more cost effective. The increased requirement for post injection exercise for $^{99m}$Tc based radiopharmaceuticals due to poorer first pass extraction efficiencies may limit the ability of the procedure compared to $^{99m}$Tc thallous chloride to detect small areas of ischaemia. The resultant referer bias may impact on the frequency of further referrals.

Variable detector gantry configurations are employed in 59.6 per cent (59/99) of departments. While there has been rapid proliferation of variable detector gantries in recent years in Australia, one might assume from anecdotal evidence that this figure is a little inflated. This may be associated with volunteer bias where departments purchasing variable detector gantries do so to address the demands of cardiac imaging and, thus, have a greater interest in the questionnaire. This is supported by the higher mean number of studies performed in departments with variable or triple detectors compared to dual opposed and single detector. This question also offers the respondent an obvious "best practice" response which may have lead to obtrusive bias where respondents provide an answer they perceive as being state of the art rather than true. While anonymity in the questionnaire minimises this, it could not be entirely excluded as a source of bias.

A 64x64 acquisition matrix is recommended for gated SPECT by the ASNC 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 (78.1 per cent) employ a 64x64 matrix for myocardial perfusion SPECT. Not surprisingly then, departments not gating studies were 2.1 times more likely to use a 128x128 matrix than those that do gate myocardial perfusion SPECT.

Attenuation correction is employed on a limited scale, however, one must recognise its developing nature in SPECT. The advantages associated with the physical properties of $^{99m}$Tc have contributed to the emergence of attenuation correction in SPECT and, thus, it comes as no surprise that departments employing $^{99m}$Tc based radiopharmaceuticals for myocardial perfusion SPECT are 2.7 times more likely to employ attenuation correction than $^{99m}$Tc departments.

It was interesting to note that 100 per cent of departments indicated that the cinainic 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 cinainic display and sinogram are displayed. This may not translate to the studies actually being evaluated adequately (or corrected) for patient motion. Perhaps a more likely cause of this figure is obtrusive bias since the question offers an obvious 'worst practice' alternative. This result is certainly counter intuitive to anecdotal evidence.

The most important results of this study relate to gating the myocardial perfusion SPECT. While only 9.1 per cent of departments do not perform gating myocardial perfusion SPECT studies, the majority (58.6 per cent) only perform gating on the stress study. The ASNC (5) 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. While the stress study is 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 28.3 per cent (28/99) of departments gate both the rest and stress studies.

It is not surprising to observe a high representation of departments employing $^{99m}$Tc in the non gating group with departments not gating being 3.3 times more likely to use $^{99m}$Tc than $^{99m}$Tc based radiopharmaceuticals. Moreover, the poor count statistics for the same acquisition time comparing a single detector gantry to triple and variable detector gantries may have contributed to the 4.3 times increased likelihood that departments not gating myocardial perfusion SPECT utilise single detector gantries. Contributing to this may be that single detector gantries may be older systems not easily conducente to gated SPECT acquisition and processing.

While the majority of departments (91.0 per cent) 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 20.9 per cent (19/91) of Australian departments employ an additional rejected beats bin, however, another 22.0 per cent (20/91) abandon gating if the perfusion data is compromised.

Only 50.5 per cent (51/101) of Australian nuclear medicine departments comply with minimum standards for acquiring myocardial perfusion SPECT recommended by the SNM. This translates to 61.9 per cent (83/135) of studies performed weekly in Australia.
Only 14.9 per cent (14/101) of Australian nuclear medicine departments comply with minimum standards for acquiring myocardial perfusion SPECT recommended by the ASNC, which translates to 17.4 per cent (235/1351) of studies performed weekly in Australia. The higher proportion of concordant studies performed compared to departments reflects the higher mean number of studies performed weekly in departments demonstrating concordance with these guidelines (16.4) compared to those discordant (10.6) \((P = 0.0001)\). Similarly, there was a higher mean number of full time equivalent technologists in concordant departments (3.7) compared to discordant departments (2.8) \((P = 0.01)\). These observations suggest that larger and busier departments are more compliant with these recommendations. The increased number of studies performed in departments complying with the recommended protocol may result, over time, from improved diagnostic integrity of the procedure resulting in more reliable diagnosis, better patient outcomes, more satisfied referring specialists and increased confidence in the procedure for these departments.

CONCLUSION

With respect to the recommended acquisition parameters outlined by both the SNM and the ASNC, only 14.9 per cent (15/101) of Australian nuclear medicine departments comply with minimum standards. Elimination of gating on both stress and rest studies as a criteria (i.e. at least one study is gated) only 50.5 per cent (51/101) of Australian nuclear medicine departments comply with minimum standards. This translates to 61.9 per cent (836/1351) of studies performed weekly in Australia. This study is concordant with the position statement of the ASNC, that while the principle of gated myocardial perfusion SPECT is without debate (only 9.1 per cent of departments in Australia do not gate), there is a requirement for investigation and guidelines for optimisation of acquisition protocols.

REFERENCES