

Experiences and Perceptions of Nuclear Medicine Technologists in the Assessment of Myocardial Perfusion Image Quality

Lucky R. Chipeya¹, Madri Jansen van Rensburg¹, and Mboyo-Di-Tamba Vangu²

¹Department of Medical Imaging and Radiation Sciences, University of Johannesburg, Johannesburg, South Africa; and ²Division of Nuclear Medicine, Department of Radiation Science, University of Witwatersrand, Johannesburg, South Africa

Nuclear medicine technologists (NMTs) are experts in the acquisition of myocardial perfusion (MP) images, in addition to the many other types of images acquired in nuclear medicine departments. NMTs are expected to ensure that images are of optimal quality in order to facilitate accurate interpretation by nuclear medicine physicians (NMPs). However, ensuring optimal image quality is a shared responsibility between NMTs and NMPs. The shared responsibilities have resulted in inconsistencies in the assessment of MP image quality among NMTs in different departments. Little is known about the perceptions and experiences of NMTs on the assessment of MP image quality. Therefore, the focus of this research study was NMTs. The aim of this qualitative study was to explore and describe the perceptions and experiences of NMTs on the assessment of MP image quality. The research question was, "How do NMTs perform the responsibility of ensuring MP image quality?" **Methods:** The study followed a qualitative explorative approach using focus groups as a means of collecting data. Nineteen NMTs from 4 academic hospitals were purposefully selected to participate. A semistructured questionnaire was used to conduct the focus groups. The collected data were managed using a computer-aided qualitative data analysis software program to formulate codes, categories, and themes. **Results:** Two overarching themes emerged from the data: the management of MP images, and the resources required to support NMTs. NMTs differed in their management of MP images because of the prevailing circumstances in their respective departments. In addition, the results suggested that NMTs' level of involvement in the assessment of MP image quality was influenced by the availability of resources required for processing and assessing image quality. **Conclusion:** Despite the shared responsibility in the assessment of MP image quality with NMPs, NMTs considered themselves as playing a major role. However, resources to facilitate the assessment of image quality are considered necessary and should be available to support NMTs in submitting images of optimal quality for interpretation.

Key Words: technologists; myocardial perfusion imaging; quality; artifacts.

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Myocardial perfusion imaging (MPI) is one of the most common imaging procedures requested in nuclear medicine

departments (NMDs) (1,2). The primary indication for MPI is to assess the relative distribution of coronary blood flow in patients with suspected or known obstructive coronary artery disease (3,4). MPI has emerged not only as a diagnostic technique but also as a robust prognostic tool able to provide data about myocardial perfusion (MP), ventricular function, and viability in a single test (5). It is therefore important that MP images be acquired and diagnosed accurately in order to decrease the risk of misdiagnosis (6).

The diagnostic accuracy of MP images is compromised by artifacts associated with localized subdiaphragmatic radiopharmaceutical concentrations in the abdominal viscera, such as the liver, stomach, and bowel (2,7), and patient motion is the most common artifact on MP images (8–10). Further, artifacts may also arise from γ -camera limitations, electrocardiography gating irregularities, and inadequate counts (8,9). Other artifacts are caused by nuclear medicine technologists (NMTs) during imaging, such as through incorrect patient positioning (8). It is important that artifacts be identified because unidentified artifacts and pitfalls have deleterious effects on the reconstructed data (11). Therefore, the quality of images should be reviewed and technical abnormalities recognized and corrected when possible by NMTs (12) during and after acquisition of images.

NMTs should be aware of sources of potential error in MPI and take appropriate steps to correct them if they occur (2,8). Before image acquisitions, NMTs perform daily uniformity and energy-peaking tests on γ -cameras; other quality control tests, such as tests of sensitivity, resolution, linearity, and center of rotation, are performed weekly (9). In addition, before the commencement of MPI, NMTs verify the integrity of electrocardiography leads by ensuring that electrical contacts are secure; otherwise, the signal can be randomly interrupted (13). If not placed properly, the R-wave gating device will not trigger on the R wave but on a different portion of the trace (13). Therefore, quality control programs are adhered to for optimizing diagnostic accuracy and ensuring consistent high-quality MP images (14).

Errors identified during image acquisition, such as extracardiac activity, require the NMT to stop the procedure temporarily, apply an appropriate intervention, such as delaying the imaging in order to allow the extracardiac activity to move away from and stop obscuring the heart, and restarting the acquisition. The NMT can also intervene after an imaging

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For correspondence or reprints, contact Lucky R. Chipeya (lchipeya@uj.ac.za).

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acquisition by using software to correct errors such as minor motion. However, in the case of major motion that cannot be corrected by software, the NMT repeats the acquisition. The NMT also uses attenuation correction software to rectify attenuation errors. The attenuation might result from inadequate counts due to variable radiation attenuation from different projection angles (13). During processing, reconstruction, and display, computer software tools help to shape and transform the images to make them more amenable to visual and quantitative analysis (15). But several user-dependent technical errors may occur during the processing phase of MP images because the user must choose the short-axis, horizontal long-axis, and vertical long-axis limits (8).

The responsibilities of NMTs in the assessment of MP image quality vary widely among different departments and countries (6,16). However, NMTs should review MP images to ensure that the required information has been obtained, is processed properly, and is of optimal quality (16). The assessment of image quality, including processing, reconstruction, and display, is within the scope of practice of NMTs (17–19). Nuclear medicine physicians (NMPs) also assess the quality of the MP images before interpretation (12). Although both NMTs and NMPs have responsibilities toward ensuring MP image quality, very little is known about the perceptions and experiences of NMTs during the assessment of MP image quality. The aim of this study was therefore to explore and describe these perceptions and experiences.

MATERIALS AND METHODS

The Research Ethics and Higher Degrees Committee of the Faculty of Health Sciences at the University of Johannesburg approved this study, and all participants individually gave written informed consent to take part in it. Further, all participants gave written permission for an audio recording to be made of the focus group discussions. Anonymity was ensured, and code names were used during discussions. It was anticipated that the participants would mention each other's names during discussions; therefore, code names were allocated at the beginning of each focus group discussion and the participants were given time to familiarize themselves with their code names.

The research study adopted a qualitative phenomenologic approach. The use of focus group discussions traded on group dynamics because the social and psychologic aspects of group behavior are used to foster the ability of the participants to get involved, speak their minds, and reflect on the views of others (20,21). In addition, focus groups are appropriate for quickly exploring topics about which little is known (22).

A purposive sampling method was adopted to select and recruit NMTs whose knowledge and work experience (23) in MPI and other nuclear medicine imaging procedures were sufficient to extract useful information. The experience of the NMTs ranged from 2 to 28 y. The focus groups were divided into 3 cohorts according to the NMD in which the NMTs worked. There were 19 NMTs in total: 7 from NMD 1, 6 from NMD 2, and 6 from NMD 3.

All the NMDs are affiliated with teaching hospitals and are accredited to teach resident NMPs and student NMTs. Consultant NMPs supervise the resident NMPs in all aspects of ensuring MP image quality and interpreting images. Likewise, during clinical placements, student NMTs are monitored by supervisory NMTs

regarding all aspects of acquiring MP images and performing quality control tests. Further, resident NMPs learn how MP images are acquired. When the NMTs submit MP images to the reporting rooms, either the resident NMPs or the consultant NMPs view the images. Therefore, the NMPs are the final referees of MP image quality, despite the NMTs' judgments.

Focus group discussions were conducted at convenient times, at venues remote from the work areas and away from disruptions (24). An interview guide was used for consistency and to direct the discussions toward significant and relevant issues pertaining to the purpose of the research study. The questions were semistructured, allowed the participants to contribute as much detailed information as they could, and permitted the researcher to probe through follow-up questions (25). The interview guide was divided into 3 areas, namely; engagement, exploration, and exit questions (26). All discussions were audio-recorded (27,28) and transcribed verbatim. Member checking was used to verify the transcriptions (24), with the participants confirming their accuracy.

Thematic analysis is the search for, and extraction of, general patterns found in data through multiple readings of data (30,31). This study used thematic analysis because it is not confined to any preexisting theoretic frameworks and can be applied to different situations (29). A qualitative data analysis software program, ATLAS.ti (version 7; Scientific Software Development GmbH), was used to manage the study data (20,32). The transcripts were uploaded into the project documents of the hermeneutic unit of ATLAS.ti, and codes, categories, and themes were developed.

Open coding was used to group similar codes to form categories under themes. During the coding, the researcher examined the data corpus as facilitated by ATLAS.ti using the NCT model (Noticing things, Collecting things, and Thinking about things), a model adapted for computer-assisted analysis (33). The final stage of the analysis was the linking of quotations to categories, and a structure was then formed from which the presentation of the results was drawn.

RESULTS

The main findings included 2 overarching themes, the management of MP images and resources to support NMTs. The first theme was developed from 3 categories, namely the assessment of MP image quality, the role of NMTs in MP image quality, and NMTs' perceptions on NMPs' assessments of MP image quality. The second theme was developed from 5 categories, namely processing workstations, user manuals, colleagues or NMPs, training, and medical imaging application specialists.

The Management of MP Images (Theme 1)

Our study confirmed the findings of Johansson et al. (16) that the extent of NMTs' responsibilities toward MP image quality varied. In NMD 1, the NMTs assessed MP image quality by processing, reconstructing, and displaying the final images. The final images were saved and submitted to the NMPs together with the raw images (unprocessed) for interpretation. In NMD 2, the NMTs followed the same procedure as the NMTs in NMD 1 but did not save the final images; instead, they submitted only the raw images to the NMPs. In NMDs 3 and 4 (both referred to hereafter as NMD 3 because they had similar procedures), the NMTs assessed MP image quality during acquisition, but once acquisition

was completed, the images were automatically submitted to the NMPs as raw images.

NMTs' Extent of Involvement in Assessing MP Image Quality. All NMTs confirmed that they were involved in the assessment of MP image quality. They also expressed their extent of involvement. The NMTs from NMD 1 considered themselves privileged to be processing and reconstructing MP images that were considered ready for interpretation:

Once everything is done, in terms of processing, you send it to the nuclear medicine physician, and most of the time they take the very same data that we have actually processed. (NMT, NMD 1)

I have been privileged to have been processing myself and then having to hand [the images] over to physicians or [resident NMPs]. (NMT, NMD 1)

Further, the NMTs from NMD 1 revealed that the NMPs request that image acquisition be repeated if the image quality was compromised, such as because of an inadequate count density or because of motion:

They just report, but if eventually they also fail to improve the quality, then they would say that the patient needs to be repeated. (NMT, NMD 1).

Again if you can't correct the motion—yes, then you have to repeat. (NMT, NMD 1)

The NMTs from NMD 2 reported processing MP images for purposes of assessing image quality and not for interpretation by the NMPs. This processing was meant to ensure that the raw images were of adequate quality:

You check for quality: your bowel, liver activity, interferences. If it's not there, fine, that's the end of the story for you. The doctors will do the processing; I think of it as a personal preference. They just prefer it that way—not that we cannot process or whatever. (NMT, NMD 2)

Lastly, the NMTs from NMD 3 assessed the MP image quality differently from those from NMD 1 or NMD 2. They reported assessing the image quality on screen and then approaching the NMPs to confirm whether the quality was optimal:

The doctors normally process their own images, but I normally check for motion, check gut activity if it's there, or I can call the doctor to double check and then from there we decide. (NMT, NMD 3)

NMTs' View of Their Role in Ensuring MP Image Quality. The NMTs from NMD 1 believed they have an impact on image quality and should be involved in the entire process, thus having the opportunity to identify errors at any stage of image processing, reconstruction, or display:

I feel that the role of the [technologist] impacts a lot on the image quality since this is the person who actually interacts with the patient from day one. I'm doing the scan. (NMT, NMD 1)

If you don't play a role in processing the whole study, you won't be able to know what you need to improve on whatever you would have done. (NMT, NMD 1)

The NMTs from NMD 2 perceived themselves as having a major role in ensuring image quality; they advocated for NMTs to do their best in ensuring optimal image quality:

Generally, what I would say is if you can do a scan, the [technologist] has to have a major part to play in the quality—basically, looking at those artifacts, like bowel and liver. (NMT, NMD 2)

Being the [technologist], you would have to do your all, making sure you are processing and bringing best-quality images to [NMPs]. (NMT, NMD 2)

I think, as [technologists], we basically look at that static image ... to produce a really good image, whereas physicians are more looking at pathology. I think we need to be involved. (NMT, NMD 3)

NMTs' Perceptions on NMPs' Assessment of MP Image Quality. Because the NMTs believed that they play a major role in ensuring MP image quality, they advocated for NMPs to be relieved of quality assurance tasks in order to concentrate on reporting MP images and other imaging procedures. However, the NMTs suggested that the NMPs could be involved in quality assurance if the NMTs find it difficult to process and assess the quality of certain MP images:

We can take some of the workload in terms of processing, and [NMPs] can be more involved with other patients. Obviously, there will still be difficult patients, but the ones that are not too complicated—that, we can process. If there is a challenge, [NMPs] can still process themselves, so we help each other out. (NMT, NMD 3)

Further, the NMTs perceived that NMPs, particularly resident NMPs, need to learn how to process and assess MP images but then would reach a point at which their involvement is limited. In addition, the NMTs assumed that the number of resident NMPs in the department would influence their involvement in processing:

Obviously, the [resident NMPs] will also need to learn, they will also get to a point where—been there, done that—they just want the end result, so it will save time for them and for the patient. (NMT, NMD 2)

Now there are a lot of [resident NMPs]. So now I think they are giving them a chance to actually do it by themselves. (NMT, NMD 2)

The NMTs from NMD 3 revealed that workloads and staff shortages made it difficult for them to find time to process and assess MP image quality. They also have to complete other imaging procedures:

There is not enough time to go and sit for processing, meaning that, basically, you've got to process at the end of the day. Sometimes, the end of the day is even late hours, so that's

where the problem comes, now and then. I suppose that's where [NMPs] also see that, "I have to process here." (NMT, NMD 3)

It always comes down to not enough personnel; we are just not enough to have an extra person sitting and processing. You must scan other patients. (NMT, NMD 3)

The NMTs perceived that when NMPs decided to process and assess MP images themselves, they were taking that responsibility because the images submitted were of suboptimal quality:

The [technologists] are sort of partly to blame for what is sent—if you have to process that same type of scan and send it to the doctor—for it to come back again for rescan. (NMT, NMD 2)

Resources to Support NMTs (Theme 2)

In every NMD, there are several resources available to produce images of optimal quality. In addition, different studies will require different resources at any given time. The NMTs acknowledged the availability of resources to support them in the processing and assessment of MP image quality. These resources included processing workstations, user manuals, colleagues or NMPs, training, and medical imaging application specialists.

Processing Workstations. The NMTs reported that processing workstations were available for NMTs to use. However, access for NMTs differed among the departments, with the workstations being either in the imaging rooms, in the NMP reporting rooms, or in special rooms:

We don't have our own for [technologists] other than the one that we have in the [imaging] room. Others have their own processing stations. (NMT NMD 2)

We have 3 [γ -cameras] and 2 processing units—well, make it 4 processing stations, out of which only 2 processing stations can be used. (NMT NMD 1)

Despite the availability of processing workstations in the imaging rooms, the NMTs in NMD 2 and NMD 3 reported that these workstations were limited in what they could do:

But [the processing units in the rooms] are limited—like basic—just to see if there is any infracardiac activity or not. (NMT NMD 3)

The reporting room has got another software; we got another one. [The processing workstations are] almost the same, but there is some additional stuff on the reporting. (NMT NMD 2)

User Manuals. User manuals are usually supplied by vendors after the installation of γ -cameras or processing workstations and are used as references for computer commands. The NMTs acknowledged their availability and usefulness but differed in their use practically:

You can actually refer to the manuals, and you get the finer details of whatever you don't understand. (NMT, NMD 1)

I would rather just do things blindly without following the manuals, because some departments have been following certain protocols of doing things and then you'll have to know them. (NMT, NMD 3)

You need another degree just to understand [the user manual]. (NMT, NMD 3)

Colleagues and NMPs. The NMTs from NMDs 1 and 2 revealed that they frequently asked for a second opinion from colleagues, especially those with more experience, and if these colleagues were unable to assist, the NMPs were consulted. The NMTs from NMD 3 preferred consulting the NMPs from the onset:

I have my colleagues for second opinion. We go for the most experienced. (NMT, NMD 1)

The first person that I will contact is my colleague to ask for a second opinion: "How do you see this?" And then, if he/she agrees with me, I'm happy, but if I'm still doubting, I will go and ask the consultant's opinion. (NMT, NMD 2)

And if you have any queries, those ones you leave for the doctors. (NMT, NMD 3)

Training. The NMTs considered training as a major resource for support in the assessment of MP image quality. They received training during work-integrated learning as students and were taught by qualified NMTs and clinical tutors. During the focus group discussions, the NMTs opined that being taught by a colleague was the best option:

The colleague will show you how to process, and you practice by yourself until you gain confidence. (NMT, NMD 1)

I think we were happy the way we were trained because we were trained through a clinical tutor. (NMT, NMD 2)

Further, the NMTs believed it was important that, after qualifying, they be given ongoing opportunities to practice what they had learned so as not to forget it:

It has been part of our training. So it's just that when we come out and we are qualified, the departments that we go to don't really allow us to process, so we lose it. (NMT, NMD 3)

You can have a structure where you go for a course or program, 1-day program. You are taught how to do things, but when you don't practice it frequently, you easily forget it. (NMT, NMD 1)

Again, the NMTs echoed the need for training of qualified NMTs. Training was deemed especially necessary for NMTs who are not actively involved in ensuring MP image quality:

We are not doing a lot of processing, but when I went to another hospital for a month, they showed me how to process, so obviously, I needed a lot of training. (NMT, NMD 2)

Training needs to be redeveloped to fill the gap for all the qualified. We have clearly lost a bit of it. (NMT, NMD 3)

Medical Imaging Application Specialists. The NMTs revealed that after installation of new equipment, medical imaging application specialists were available to train them but did not have all the answers and were not readily available if the NMTs require assistance after the training period:

[Medical imaging application specialists] usually come on installation day, and if the department doesn't know the software or... the machine, they come and do everything, and they go, leave the manuals, and it's for you to remember what they said and how the things work. (NMT NMD 2)

You can often ask them the questions and they don't have answers because they don't have the clinical experience. (NMT, NMD 3)

They won't come, like, tomorrow, but they would like to come later on to see the progress. On your day 1 of the training session, you may not be able to ask a lot of questions because you don't know anything about this equipment. Once you start using the machine, you now start experiencing problems. (NMT, NMD 1)

DISCUSSION

The NMTs from the different NMDs expressed different and similar perceptions and experiences about processing MP images and assessing their quality. Because of the paucity of published literature on this topic, parallels are drawn from similar professions in the medical field, such as diagnostic radiography and nursing. These professions share some responsibilities with other professions, diagnostic radiographers with radiologists and nurses with physicians (34).

The NMTs from the different departments ensured that the MP images submitted to the NMPs for reporting were assessed for quality. However, those who assessed MP raw images were likely to miss artifacts that appear during processing and reconstruction. Artifacts may arise at any stage of MPI (9). In addition, processing is not a substitute for poor positioning techniques (35). Therefore, if NMTs process the MP images during the assessment of quality, they can identify artifacts that may arise during processing and they can see how positioning affects the resultant images. This capability would help NMTs realize the effects of acquisition parameters, patient positioning, and other variables during acquisition of the final images.

The NMTs' suggestion that they be more involved than NMPs in the processing and quality assessment of MP images, to allow the NMPs more time for reporting, was also expressed by diagnostic radiographers in a study by Brealey and Scuffham (36). This study found that training diagnostic radiographers on how to report examinations for patients referred from accident and emergency departments afforded radiologists the time to concentrate on other reporting duties. The same could be said of NMTs trained to process and assess MP images in order to release NMPs from image-quality responsibilities, allowing them to concentrate on MPI

reporting and other procedures. In the United Kingdom, adoption of an enhanced role for NMTs in stress testing enabled the nuclear cardiology service to effectively increase its capacity for stress sessions, thus allowing NMPs to focus on reporting, clinical research, and development of the clinical service (37).

If an organization develops adequate resources to help NMTs achieve the goal of ensuring optimal MP image quality (38,39), it would seem possible for them to assume responsibility for processing and assessing MP images. Such resources differed among the 3 NMDs. User manuals were available but were underutilized by the NMTs. Instead, the NMTs relied on following the protocols established locally by their departments, as was also reported by Sá Dos Reis et al. (40). Because such protocols were favored over user manuals and sometimes were adaptations or simplifications of the user manuals, these protocols should be optimized, with the manuals serving as a backup.

Support from colleagues in the workplace is important in any organization. Our finding that NMTs relied on colleagues as a first line of support was also reported by Choi (41), whose study found that team members of similar educational levels helped each other. However, a decision to first approach NMPs, rather than colleagues, for image-quality opinions could be due to lack of confidence in colleagues whose involvement in image-quality assessment is limited. It is therefore important that NMTs be adequately trained to submit images that are of optimal quality and will not need to be repeated.

It seemed acknowledged that medical imaging application specialists are made available to train NMTs on how to use new equipment. However, after the training session, these specialists were no longer available on site to respond to any challenges the NMTs might later experience. Instead, the specialists left behind user manuals as a reference, which the NMTs found difficult to use and did not often consult. NMDs could consider recalling the specialists for further training, especially once the NMTs have started using the new equipment. Nonetheless, since MP image processing and assessment of quality are part of formal clinical training for NMT students, it is important that after qualification, they have an opportunity to practice and update the acquired skills in order not to become obsolete. In another study, NMTs and radiation therapists advocated for more training on technologic developments, preferably facilitated by their respective departments (42). Therefore, ongoing in-house training and practice should be the norm. The NMPs and senior NMTs could conduct regular in-house training sessions on predetermined schedules.

Our findings are limited to the NMTs who participated in this study and therefore cannot be generalized beyond them, as is the nature of a phenomenologic research study. However, the useful information that emerged on the perceptions and experiences of NMTs in the assessment of MP image quality—a shared responsibility with NMPs—could elicit further research in this area.

CONCLUSION

The burden of MPI on the patient from the stress testing procedure, the length of stay, the cost, and the impact of the results should be taken seriously. Therefore, it is important that the MP images submitted by NMTs to NMPs for interpretation be of optimal quality. It is also important for NMTs to display confidence and assume ownership of MP image quality so that MP image processing, assessment of image quality, and reconstruction will be meticulously executed. To facilitate production of optimal MP images, resources should be available and effectively used by NMTs. Since ensuring optimal MP image quality is a shared responsibility between NMTs and NMPs, management of the MP images should be well coordinated with the NMTs. When followed carefully, clearly written protocols for the processing and reconstruction of MP images can improve this process. Therefore, such protocols are recommended.

DISCLOSURE

No potential conflict of interest relevant to this article was reported.

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