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EXPERIENCES AND PERCEPTIONS OF NUCLEAR MEDICINE TECHNOLOGISTS IN THE ASSESSMENT OF MYOCARDIAL PERFUSION IMAGE QUALITY

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ABSTRACT

Introduction: Nuclear medicine technologists are experts in the acquisition of myocardial perfusion images, including many other images performed in nuclear medicine departments. They are expected to ensure that images are of optimum quality in order to facilitate accurate image interpretation by nuclear medicine physicians. However, optimum image quality assurance is a shared responsibility between nuclear medicine technologists and nuclear medicine physicians. The shared responsibilities resulted in inconsistences in the assessment of myocardial perfusion image quality among nuclear medicine technologists in the respective departments. Little is known about the perceptions and experiences of nuclear medicine technologists on the assessment of myocardial perfusion image quality. Therefore, the focus of this research study was on nuclear medicice technologists.

Aim: The aim of this qualitative study was to explore and describe the perceptions and experiences of nuclear medicine technologists on the assessment of myocardial perfusion image quality. The research question was "how do nuclear medicine technologists perform the responsibility of myocardial perfusion image quality?"

Method: The study followed a qualitative explorative approach using focus groups as a means of collecting data. Nineteen nuclear medicine technologists from four academic hospitals were purposefully selected to participate. A semi- structured questionnaire was used to conduct the focus groups. The collected data was managed using ATLAS.ti version 7, a computer aided qualitative data analysis software to formulate codes, categories and themes.

Results: Two overarching themes emerged from the data. (1) The management of the myocardial perfusion images (2) resources required to support nuclear medicine technologists. The nuclear medicine technologists differed in their management of myocardial perfusion images, due to the prevailing circumstances in their respective departments. In addition, the results suggested that nuclear medicine technologists' level of involvement in the assessment of myocardial perfusion 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 myocardial perfusion image quality with nuclear medicine physicians, the nuclear medicine technologists considered themselves playing a major role. However, resources to facilitate the assessment of image quality are considered necessary and should be available to support the nuclear medicine technologists to submit images of optimum quality for interpretation.

Keywords: technologists, myocardial perfusion imaging, quality, artifacts.

INTRODUCTION

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). Myocardial perfusion imaging has emerged not only as a diagnostic technique but also 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 are 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 localised sub-diaphragmatic radiopharmaceutical concentration in the abdominal viscera, such as the liver, stomach and bowel (2,7) and patient motion is the most common artifact on MP images (8,9,10). Further, artifacts may also arise due to gamma camera limitations, ECG gating irregularities, and inadequate counts (8,9). Other artifacts are caused by nuclear medicine technologists (NMTs) during imaging such as incorrect patient positioning (8). It is important that artifacts are 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 be recognised and corrected where possible by NMTs (12) during and after acquisition of images.

Nuclear medicine technologists 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, the NMTs perform daily uniformity and energy peaking on gamma cameras, other quality control tests such as sensitivity, resolution, linearity and centre of rotation are performed weekly (9). In addition, prior to the commencement of MPI, the NMTs verify the integrity of ECG leads, by ensuring that electrical contacts are secure or else the signal can be randomly interrupted (13). If not placed properly the supposed 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 extra cardiac activity, requires the NMT to stop the procedure temporally, apply appropriate intervention, such as delay imaging in order to allow the extra cardiac activity to move away from obscuring the heart and restarting the acquisition. The NMT can also intervene after imaging acquisition by using available software to correct errors such as minor motion. However, in case of major motion which motion correction software cannot correct, the NMT repeats the acquisition. The NMTs also use the available attenuation correction software to rectify the attenuation errors. The attenuation could result from inadequate counts due to variable radiation attenuation from different projection angles (13). The NMTs therefore use the available attenuation correction software to rectify the error. 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 a number of technical errors may occur during the processing phase of MP images because the choice of short, horizontal long and vertical long axis limits are selected by the user (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 optimum quality (16). The assessment of image quality including processing, reconstruction and display is within the scope of practice of NMTs (17,18,19). The NMPs also assess the quality of the MP images before interpretation (12). Despite the fact that both the NMTs and NMPs have responsibilities towards MP image quality, the focus of this research study was on NMTs*, and* very little is known about the perceptions and experiences of NMTs during the assessment of MP image quality. Therefore, the aim of this study was to explore and describe the experiences and perceptions of NMTs during the assessment of MP image quality.

METHOD

The Research Ethics and Higher Degrees Committee of the Faculty of Health Sciences at the University of Johannesburg approved this study and all participants (subjects) individually signed a written informed consent to take part in this study. Further, permission to tape record the focus group discussions was granted by all participants in writing. Anonymity was assured 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 phenomenological approach and focus group discussions were conducted with NMTs. The use of focus groups in this research study traded on group dynamics because focus groups use the social and psychological aspects of group behaviour 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 the NMTs to participate and share their perceptions and experiences in the assessment MP image quality. The NMTs' knowledge and work experience (23) in MPI and other nuclear medicine imaging procedures was sufficient to extract useful information. The experiences of the NMTs ranged from two to 28 years. The focus groups where divided into three cohorts according to the NMDs the NMTs worked in. The NMTs who participated were (n=7), (n=6) and (n=6) from NMD1, NMD2 and NMD3 respectively and were 19 in total.

All the NMDs are affiliated to teaching hospitals and are accredited to teach nuclear medicine residents in training and nuclear medicine student technologists. In relation to MPI, consultant NMPs supervise the nuclear medicine residents in training in all aspects of MP image quality and interpretation. On the contrary, the nuclear medicine student technologists are supervised by NMTs in all aspects of MP image acquisition and quality control during clinical placements. Further, the nuclear medicine residents in training learn about MP image acquisitions to familiarise themselves with how images are acquired. When the NMTs submit MP images to the reporting rooms, either the nuclear medicine residents in training or the consultant NMPs view the images. Therefore the NMPs are the final referees of the MP image quality, despite the NMTs judgements.

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 focus groups discussions. The interview guide consisted of significant and relevant issues pertaining to the purpose of the research study. The questions were semi-structured and allowed the participants to contribute as much detailed information as they could and, at the same time, permitted the researcher to probe through follow-up questions (25). The interview guide was divided into three areas, namely; engagement, exploration and exit questions (26). All the focus group discussions were captured with the use of a tape recorder (27,28) and were transcribed verbatim. The member checking process was undertaken as a means of verifying the accuracy of the transcribed participants' audiotaped focus group discussions (24) and the participants confirmed the accuracy of transcriptions.

Thematic analysis was used for this study because it is not confined to any pre-existing theoretical frameworks and can be used within different frameworks and in different situations (29). Further, thematic analysis is the search for, and extraction of general patterns found in the data through multiple readings of the data (30,31). ATLAS.ti version 7, a qualitative data analysis software was used to manage the study data (20,32). The transcripts were uploaded into Project Documents of the hermeneutic unit of ATLAS.ti version 7 and codes, categories and themes were developed.

Open coding was undertaken by grouping the codes according to similarities to form categories under themes. During the process of coding, the researcher examined the data corpus as facilitated by ATLAS.ti using the NCT model (**N**oticing things, **C**ollecting things and **T**hinking about things), a model adapted for computer-assisted analysis procedures (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 two overarching themes, the management of MP images and resources to support NMTs. The first theme was developed from three categories, namely, the assessment of MP image quality, the role of NMTs in MP image quality and NMTs' perceptions on NMPs assessment of MP image quality. The second theme was developed from five categories, namely, processing workstations, user manuals, colleagues and NMPs, training and medical application specialists.

The management of MP images (Theme 1)

As mentioned by Johansson et al, (6), in this study, it was confirmed that the extent of NMTs' responsibilities towards MP image quality varied. In nuclear medicine department (NMD1), the NMTs assessed the 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 nuclear medicine department 2 (NMD2), the NMTs followed the same procedure as the NMTs in NMD1, but did not save the final images, instead they submitted only the raw images to the NMPs. In nuclear medicine departments 3 and 4, (named NMT3 because of 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.

Assessment of MP image quality

The NMTs from the different NMDs confirmed involved in the assessment of MP image quality. They also expressed their extent of involvement. The NMTs from NMD1 considered themselves privileged to be processing and reconstructing the MP images 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, NMD1).*

> *I have been privileged to have been processing myself and then having to hand it* (the images) *over to physicians or registrars* (nuclear medicine residents in training) *(NMT, NMD1).*

Further, the NMTs from NMD1 revealed that the NMPs request repeats of image acquisition if the image quality was compromised, for example, due to inadequate count density or 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, NMD1)*

> *Again if you can't correct the motion yes, then you have to repeat. (NMT, NMD1)*

The NMTs from NMD2 reported processing MP images for purposes of assessing image quality and not for interpretation by the NMTs. This 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 it as a personal preference. They just prefer it that way, not that we cannot process or whatever. (NMT, NMD2)*

Lastly, the NMTs under NMD3 assessed the MP image quality differently from NMD1 and NMD 2. They reported assessing the image quality on screen and then approached NMPs to confirm whether or not the images were of optimum quality.

> *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, NMD3).*

The role of NMTs in MP image quality

The NMTs from NMD1 expressed the view that NMTs have an impact on image quality and they should be involved in the entire process of MP image quality. This would give them the opportunity to identify errors, should they occur in all the stages of image processing, reconstruction and display.

> *I feel that the role of the radiographer* (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, NMD1).*

> *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, NMD1).*

In addition, the NMTs from NMD2 perceived themselves playing a major part in image quality and advocated for NMTs doing the best in ensuring optimum image quality.

> *Generally, what I would say, if you can do a scan, the radiographer* (technologist) *has to have*

a major part to play in the quality, basically, looking at those artifacts like, bowel and liver. (NMT, NMD2)

Being the radiographer (technologist), *you would have to do your all, making sure you are processing and bringing best quality images to them (NMPs). (NMT, NMD2)*

I think, as radiographers (technologists)*, we basically look at that static image you know, to produce a really good image whereas physicians are more looking at pathology. I think we need to be involved (NMT, NMD3).*

NMTs' perceptions on NMPs' assessment of MP image quality

Since the NMTs were of the view that they play a major role in MP image quality. They advocated for NMPs to be relieved of MP image quality tasks for them to concentrate on reporting MP images and other imaging procedures. However, the NMTs suggested that the NMPs could be involved if the NMTs find it difficult to process and assess the image quality of certain MP images.

We can take some of the workload in terms of processing and they can be more involved with other patients, obviously, they will still be difficult patients, but the ones that are not too complicated, that we can process. If there is a challenge, they can still process themselves so we help each other out. (NMT, NMD3)

Further, the NMTs perceived that NMPs, in particular the nuclear medicine residents in training, needed to learn how to process and assess the MP images and would reach a point where their involvement will be limited. In addition, the NMTs assumed that the number of nuclear medicine residents in training in the departments influenced their involvement in processing.

*Obviously the registrars (*nuclear medicine resident in training) *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, NMD2)*

Now there is a lot of registrars (*nuclear medicine resident in training). So now I think they are* *giving them a chance to actually do it by themselves. (NMT, NMD2)*

The NMTs from NMD3 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 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 they* (NMPs) *also see that, "I have to process here." (NMT, NMD3)*

> *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, NMD3)*

The NMTs perceived that the NMPs took the responsibility of processing and assessment of the MP images quality because the images submitted were of sub-optimum quality.

> *The radiographers* (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 re-scan (NMT, NMD2).*

Resources to support NMTs (Theme 2)

In every NMD, there are a number of resources available to use in order to produce images of optimum 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 were, processing workstations, user manuals, colleagues or NMPs, training and medical imaging specialists.

Processing workstations

The NMTs reported that processing workstations were available for NMTs to use. However, access for NMTs differed in each of the departments the participating NMTs worked in. The NMTs reported that processing workstations for the processing and assessment of image quality were either in the imaging rooms, NMPs' reporting rooms or special rooms.

> *We don't have our own for radiographers* (technologists) *other than the one that we have in the room (imaging room). Others have their own processing stations. (NMT NMD2)*

> *We have three machines (*gamma cameras) *and two processing units, well make it four processing stations, out of which only two processing stations can be used. (NMT NMD1)*

Despite the availability of processing workstations in the imaging rooms, the NMTs in NMD2 and NMD3, reported that the processing workstations in the imaging rooms were limited in what they could do in processing.

> *But, it's limited (*processing units in the rooms)*, like basic, just to see if there is any infra cardiac activity or not, so you are able to see that. (NMT NMD3).*

> *The reporting room has got another software we got another one. They're (*processing workstations) *almost the same but there are some additional stuff on the reporting (NMT NMD2).*

User manuals
User manuals

User manuals are usually supplied by vendors after the installation of gamma 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, NMD1)*

> *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, NMD3)

> *You need another degree just to understand it, (*user manual) (NMT, NMD3)

Colleagues and NMPs

The NMTs from NMD1 and NMD2 revealed that colleagues were frequently consulted for second opinion especially those with more experience. The NMPs were subsequently consulted if colleagues were unable to assist. The NMTs from NMD3 preferred consulting the NMPs from the onset.

> *I have my colleagues for second opinion. We go for the most experienced.* (NMT, NMD1)

> *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, NMD2).*

> *And if you have any queries, those ones you leave for the doctors (NMT, NMD3).*

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 groups, the NMTs mentioned that being taught by a colleague was considered the best option.

> *The colleague will show you how to process and you practice by yourself until you gain confidence (NMT, NMD1).*

> *I think we were happy the way we were trained because we were trained through a clinical tutor (NMT, NMD2).*

Further, the NMTs revealed that it was important that, after qualifying, opportunities are made available to practice what was learned as students because processing was part of their training and it should be ongoing otherwise they will forget if not practiced.

> *It has been part of our training. So it's just that, when we came out and we are qualified, the departments that we go to don't really allow us to process so we lose it. (NMT, NMD3)*

You can have a structure where you go for a course or programme, one day programme. You are taught how to do things, but when you don't practise it frequently, you easily forget it. (NMT, NMD1)

Again, the NMTs echoed the need for training for qualified NMTs. Training was deemed necessary especially the NMTs who were not actively involved in 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, NMD2)

Training needs to be re-developed in order to fill the gap for all the qualified, we have clearly lost a bit of it. (NMT, NMD3)

Application imaging specialists

The NMTs revealed that application imaging specialists were available to train them after installing new equipment even though they were considered not to have all the answers and were not readily available if the NMTs required assistance after training.

*They (*application imaging specialists) *usually come on installation day and if the department doesn't know the software or whatever 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 NMD2)*

You can often ask them the questions and they don't have answers because they don't have the clinical experience, (NMT, NMD3)

They won't come like tomorrow, but they would like to come later on to see the progress. On your day one 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, NMD1)

DISCUSSION

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

The NMTs from the different departments ensured that the MP images submitted to the NMPs for reporting were assessed for image quality. However, those who assessed MP planar images were likely to miss our artifacs which appear during processing and reconstruction. It is cited that artifacts may arise at any stage of MPI (9). In addition, processing may not be substituted for poor positioning techniques (35). Therfore, if NMTs process the MP images during the assessment of image quality, they can identify artifacts which may arise during processing and the effects of positioning on the resultant images. This would assist the NMTs in realising the effects of acquisition parameters, patient position among others executed during acquisition on the final images.

The suggestion by the NMTs that they should be involved in the processing and assessment of MP image quality to a greater extent than NMPs in order to allow them more time for reporting was also expressed by diagnostic radiographers in a study by Brealey and Scuffham (36) who after proper training in the reporting on examinations for patients referred from accident and emergency departments, afforded radiologist time to concentrate on other reporting duties. The same could be said about NMTs engaging in processing and assessment after proper training could release NMPs from image quality responsibilities and concentrate on MPI reporting and other procedures. Through the adoption of an enhanced NMT role in stress testing in the UK, the nuclear cardiology service was able to effectively increase the capacity for stress sessions, which allow NMPs to focus their resources on reporting, clinical research and development of the clinical service (37). Nonetheless, it would seem possible for the NMTs to assume the responsibilities for processing and assessment of MP image quality if adequate resources are available to help the NMTs achieve optimum MP image quality.

Resources to support NMTs in the processing and assessment of MP image quality differed between the NMDs from which the participants worked in. Resources are things perceived to help one achieve goals (38) and so that the organisation may develop (39). User manuals were available in the NMDs as part of the resources available to assist in the processing and assessment of MP image quality but were underutilized by the NMTs. Instead, the NMTs relied on established protocols in their departments. Sá Dos Reis et al, (40) reported that radiographers used protocols developed locally in their departments. Since the protocols developed in the departments were favoured over user manuals, the protocols should be used optimally and user manuals if supplied can be used as backup because some of the developed protocols are adopted from user manuals and simplified.

Support from colleagues in the work place is important in any organization. Opting for colleagues to assist as the first line of support by the NMTs in this study was also reported in a study by Choi (41) in which team members of similar educational level were found to help each other. However, the NMTs who approached NMPs first for opinions of image quality instead of colleagues could be due to lack of confidence in their colleagues whose involvement in the assessment of MP image quality was limited. It is therefore important that the NMTs are adequately trained so that images submitted for interpretation are of optimum quality and do not require repeating.

Medical imaging application specialists seemed acknowledged in training NMTs on new equipment. However, after training, they were reported unavailable on site to respond to challenges experienced by the NMTs which may arise at a later stage. Instead, they supply user manuals as reference which the NMTs do not often use and were found not easy to use. The NMDs could consider recalling the application specialists for further training especially once the NMTs start using the newly installed equipment. Nonetheless, since processing and assessment of MP image quality is part of formal clinical training for nuclear medicine technologist students, it is important that after qualification, the acquired skills are practiced and updated in order not to become obsolete. In another study, radiographers, NMTs and radiation therapists, advocated for more training aimed at increasing knowledge related to technological developments, preferably facilitated by their respective departments (42). Therefore, ongoing in-house training and practising should be the norm. The NMPs and senior NMTs could conduct regular in-house training at predetermined schedules.

LIMITATIONS

The findings in this study are limited to the cohort of NMTs who participated in this study. Therefore, they cannot be generalized beyond the participants under study, which is the nature of a phenomenological research study. However, useful information on the perceptions and experiences of NMTs in the assessment of MP image quality a shared responsibility with NMPs emerged which 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 results have on patients should be taken seriously. Therefore, it is important that the MP images submitted by NMTs to the NMPs for interpretation are of optimum quality. It is also important for NMTs to display confidence and assume ownership of the MP image quality so that MP image processing, assessment of image quality and reconstruction will be meticulously executed. In order to produce images of optimum quality, resources should be available and be effectively used to facilitate the production of optimum MP images by the NMTs. Since MP image quality is a shared responsibility between the NMTs and NMPs, the management of the MP images should be well coordinated with the NMTs to ensure optimum MP image quality. Clearly written protocols for the processing and reconstruction of MP images can improve this process when followed carefully. Therefore, such protocols are recommended.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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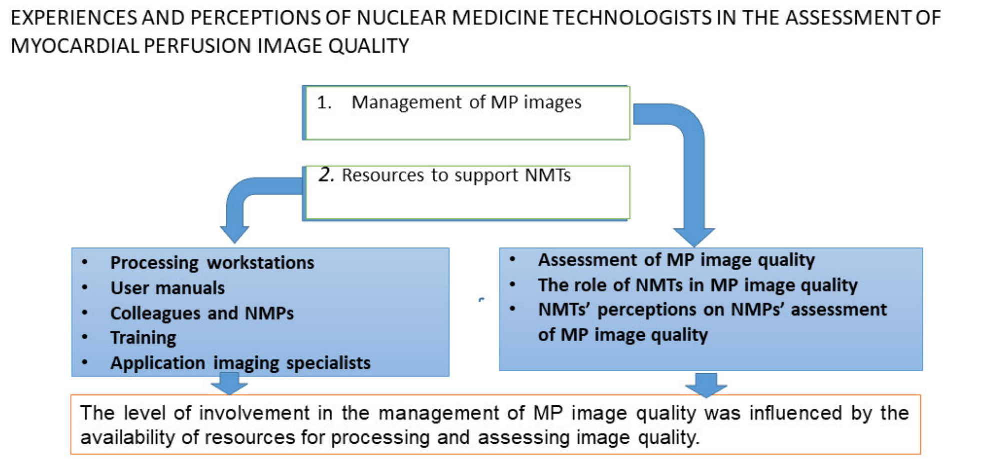
Graphical Abstract



Implications: Resources to facilitate the assessment of image quality are necessary and should be available to support the NMTs in submitting images of optimum quality for interpretation.