J of Nuclear Medicine Technology, first published online July 9, 2021 as doi:10.2967/jnmt.120.257592

Brain Imaging Techniques: Improving the Quality

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Brief Title: Brain Imaging Techniques

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Word Count: 3834

Abstract

Image quality is one of the utmost important factors in nuclear medicine. Regardless of what type of scan is being done, technologists should be diligent in how images are being acquired. In respect to brain imaging, there can be challenges that the technologist will need to understand how to navigate through and overcome. Throughout this continuing education article, different image quality complications will be mentioned and how it affects image outcome. The purpose of this article is to help technologists gain a better understanding of how artifacts can occur and how imaging techniques can affect image quality. This document will mainly focus on SPECT brain imaging, DaTscans and, (18)F-fluorodeoxyglucose (FDG) PET/CT brain imaging.

Key words: quality, brain, techniques, artifacts

There are many variables that can affect the quality of imaging. These variables can range from technical/mechanical problems to patient and technologist issues. It is imperative that technologists obtain sufficient training to be competent in quality imaging techniques regardless of the nuclear medicine scan being done. Errors in following proper imaging protocol, understanding the isotope being used, and not keeping up to date with instrumentation quality control (QC) can affect the outcome of imaging quality. In turn this can cause misinterpretation of images and incorrect outcomes for patients.

This article will cover brain imaging quality techniques, different types of brain imaging scans and considerations for imaging quality. It will also review the importance of the isotopes being used. These techniques can be intermingled with both single-photon emission computed tomography (SPECT) and positron emission tomography-computed tomography (PET/CT). The goal of this continuing education article is to help technologists to gain up to date information on best practices for brain imaging.

What makes a Quality Image

A high quality image produces the best possible resolution and contrast that allows for an accurate diagnosis (*1*). There are several factors that go into ensuring that a high quality nuclear medicine image is produced. These factors can differ between the imaging device being used, patient dependent, isotope being used, and technologists capability (*1*). To go more in depth, properties that include sub-optimal camera QC, spatial resolution, non-uniformity, incorrect energy resolution, patient preparation, technologist education and understanding of protocols, instrument artifacts, patient artifacts, adequate patient dose, camera parameters, and image interpretation can impact the integrity of the image *(1)*.

All the above listed variables, along with others not listed, need to be taken into consideration without any negligence on the part of the technologist. If these variables can be avoided, you can be assured that high quality images of your patient will be taken each and every time. It is especially important that protocols are standardized throughout institutions to ensure that each technologist is doing proper imaging techniques to keep the quality assurance of images. Furthermore, it is paramount that technologists are capable of adequately overcoming imaging challenges when they arise.

Patient Preparation

One of the first steps to ensure proper imaging techniques is to correctly prepare the patient for the imaging scan if needed. Depending on what type of scan you are performing, the patient may need to be off certain medications and fasting for a specific amount of time. Each scan will have its own specific protocol that the technologist will need to be familiar with.

For I-123 Ioflupane (DaTscan) imaging, patients will need to be off any medication or drug that has the possibility of binding to the dopamine transporter *(2)*. This may impact the ability of I-123 Ioflupane to fully bind to the dopamine transporter. DaTscan patients will also need to be prepped with an iodine solution, 400mg of potassium perchlorate, single dosage of potassium iodide or single dosage of Lugol's solution. Single dosages are equal to 100mg of iodine. This will prevent any free I-123 to uptake into the thyroid gland *(2)*.

Brain perfusion SPECT imaging does not require as much patient preparation as some other scans. Patient's will need to try to avoid substances that can affect brain perfusion. This can include alcohol, caffeine, stimulants, smoking, and any other drug that may interact with cerebral perfusion *(3)*. The technologist should be aware of pre-injection protocols that allow for best possible cerebral uptake. The patient should be placed in a dimly-lit room that is quiet. Once intravenous access has been obtained, the technologist should wait 10-15 minutes before doing the radiopharmaceutical injection to allow the patient to become calm after the IV has been inserted. Having the patient relax, keeping the eyes open prior to injection is also important . If the patient's eyes are closed at the time of injection, this can cause hypometabolism of the occipital lobe which can then cause a false positive of dementia with Lewy bodies *(4)*. The patient will also need to be instructed not to read or speak for approximately 5 minutes before and after injection *(3)*.

Pre and post injection preparation for FDG PET/CT brain imaging is similar to brain perfusion SPECT imaging in the sense that patients will need to be placed in a calm, dimly-lit room. IV access should be done about ten minutes prior to injection. If injection is done any sooner, it could cause false uptake in the pain center of the brain. The technologist also should not talk with the patient during injection to prevent uptake in the hearing area of the brain. Once injection of the radiopharmaceutical is complete, the patient will need to keep their eyes open but avoid speaking, reading and any considerable amount of movement during the duration of the 30 minutes uptake period *(5)*.

Moreover, for FDG PET/CT brain imaging, patients will need to come to the department having fasted for 4-6 hours. This includes no alcohol, drugs or caffeine. Hydrating with water orally is acceptable. The patient's blood glucose levels will also need to be checked. Protocol on this may differ from facility to facility but most commonly, if blood glucose is greater than 150-200mg/dL, the patient will be rescheduled for a later date when lower blood glucose can be achieved *(5)*.

Mechanical Artifacts

Several different types of mechanical artifacts can occur causing a decrease in image quality. It is essential that camera QC is kept up to date to avoid any chance in a decline of image quality. QC may differ between camera manufacturers and the technologists need to be familiar with how to perform the routine QC on the camera they will be working on. One of the main QC procedures that needs to be done on the camera is daily uniformity. This can be done either extrinsically or intrinsically. It will depend on the camera manufacturer. The main purpose of the daily uniformity procedure is to define the detectors response to a source. It will check this response to be sure it is within the defined limits. This QC has the ability to identify multiple different issues with the camera that can cause a degradation of image quality. These can include issues with the photomultiplier tubes, unsuitable spatial linearity, and energy correctly or it can also reveal generalized degradation of uniformity in images *(6)*.

Spatial resolutions and linearity along with center of rotation (COR) will also need to be done on camera. Again, the specific protocol will vary between manufacturers. Spatial resolution and linearity will help determine long term degradation of camera resolution rather than acute changes *(6)*. It will also indicate if something was adjusted incorrectly during maintenance. COR QC is important for any SPECT imaging that will be done. If the COR is not in a straight line across the axial direction and does not have the sine wave shape across the other axis, this could mean that the COR is moving and not centered accurately. Therefore, causing blurring in the image and resolution degradation *(6)*. It is important that the COR is done with each zoom and collimator that is used for SPECT imaging.

High count floods are also another QC procedure that can help check for non-uniformities around the center axis of rotation. The filtered back projection that is used during the flood will help showcase any ring artifacts happening *(6).* This high count floor should only be performed during acceptance testing or if there is any speculation of damage to any of the collimators *(6)*.

As you can see, not staying up to date on camera maintenance and QC can cause a high degree of image quality loss. The camera manufacturer should be notified if any of the QC results fall outside of desired values set by the manufacturer. If the camera is still in use with undesirable QC values this can cause inaccurate findings on patient images and degradation of quality and resolution. This will allow for suboptimal patient care and possible treatment. (Figure 1)

Technologist Artifacts

As a technologist, you need to have adequate training and understanding of the nuclear medicine procedures you will be performing. If you do not, it can lead to technologists triggered artifacts and can in turn, result in uninterpretable images. Just to name a few, some common errors can include poor image processing, lack of patient education/preparation, not monitoring patients for motion, incorrect dosage, and not operating the camera correctly. (Figure 2)

These common errors that can happen are especially important to avoid when it comes to brain imaging. Mistakes such as not bringing the detectors to the correct distance from the patient can impact image quality. For example, the radius of the detectors relative to the patient for a DaTscan should be between 11-15cm *(2)*. If the radius is larger than that given range, it can cause blurring. (Figure 3) The technologist needs to be familiar with how many counts as well as correct scan length is adequate for the scan being done. DaTscans require a minimum of 1.5 million counts total for the entirety of the scan *(2)*.

Scan time for PET/CT will depend on what type of camera is being used. SPECT brain requires 60 or greater number of stops and the scan length should be limited to between 30-45 minutes *(7)*. This will help reduce patient uncomfortability and motion. Insufficient counts or camera stops can produce suboptimal images that may be uninterpretable by a radiologist.

Constant monitoring of the imaging facility by the technologist and management can help reveal practices and performances that need improvement. Quality improvement is an option to examine performance within the imaging facility with the help of data analysis. A Practical Guide to Quality Improvement in Nuclear Medicine lays out a very useful 10-step process that can help facilities improve the quality of performance within their lab *(8)*.

The 10-steps of quality improvement include: 1) Identifying a potential problem or area of concern, 2) Gathering information and understanding the full extent of the problem, 3) Stating the goal and set goal targets, 4) Designing a data collection strategy, 5) Collecting data, 6) Analyzing that data, 7) Sharing the results of the data, 8) Implement the needed changes, 9) Recollecting data 10) Analyze *(8)*. Following these 10 steps can help suboptimal performance to be identified which gives the opportunity to improve on flaws in performance. A step-by-step checklist plan like this can help reduce technologist artifacts and mistakes made in imaging and help reduce the number of rescanning of patients.

Patient Positioning

Patient positioning can be considered to be one of the more critical steps in a protocol. A head holder should be used for brain imaging. Prior to getting the patient on the imaging table, they should be encouraged to void to help evade disruption during the scan. Patients will also need to remove eyeglasses, hats, earrings and any other items that can interfere with the image. Technologists should help the patient get as comfortable as possible on the table. This may include a knee bolster to help alleviate pressure on the lower back or a blanket to keep the patient warm. A body strap around the patient can also be utilized to make sure the patient is secure and comfortable on the imaging table during the scan. Once the patient has been made comfortable, straps across the patient's forehead and/or chin can be used to help prevent motion during imaging (9).

The canthomeatal line is a standard positioning line used for most brain scans. It is an imaginary line from the lateral canthus and extends to the center of the auditory meatus. Basing your patient positioning off this imaginary line will help ensure that the entire brain is included in the imaging. If the patient's head cannot be tilted to allow for the canthomeatal line to be vertical to the imaging table, it is of greater importance that the patient is in a comfortable position. In the case of not being able to position the patient’s canthomeatal line vertical to the imaging table, proper orientation of the patient’s brain during processing can be achieved. Thorough communication with the interpreting physician should be done, explaining that the patient was difficult to position. (Figure 4)

Precautions

Technologists need to take into consideration the type of patient they are going to be taking care of. There are a few precautions that may need to be addressed. The technologist should be flexible in knowing that depending on the type of brain scan they will be doing, may determine the actions of a patient and some extra care may be needed to get a scan done. For example- for DaTscan imaging, patients might move so securing and immobilizing the head is extremely important. Extra time should be taken to ensure proper head placement and that chin and head straps should be used to ensure the patient remains still during the entire scan. For FDG PET/CT brain imaging, these patients might be cognitively impaired and may not remember the instructions told to them. Repeating these instructions several times may be needed to make certain compliance with holding still on the imaging table.

Monitoring patients is also an important precaution that technologists need to take into account. It may be necessary to give special attention and monitoring to patients with neurological defects *(10)*. Brain imaging scans can be difficult for some patients to complete so monitoring the patient will ensure that the patient is comfortable throughout the entirety of the scan and not moving. Straps placed across the forehead and chin may help in keeping the patients head in the correct position for the duration of the scan and aid in eliminating patient motion. For patients with epilepsy, it is especially important for patients to be monitored correctly. This can include continuous recording of the patient if being done for preoperative evaluation.

It is not uncommon for patients to need a mind altering drug, such as a sedation, to help get them through a scan. If sedation is needed, for a PET/CT brain scan specifically, it should be given as late as possible after the uptake period (5). If needed for a DaTscan, this can be done prior to imaging (2). For SPECT brain scans, the sedation can be administered after injection of the radiopharmaceutical (10). Sedation can be helpful for patients that are claustrophobic, have difficulty lying still, dementia patients or uncooperative patients.

Image Interpretation

Image quality should be checked prior to image interpretation. Cine or sinograms should be checked for motion and head alignment. Target-to-background and other artifacts such as contamination, attenuation, patient motion, and undesired radiopharmaceutical uptake should be assessed. If there are difficulties with patient motion, you can acquire images in list mode. This will allow for reconstructing it into a shorter interval acquisition in the case of movement in the last minute. Precaution needs to be taken when levels of contrast are selected as some color scales can be misleading during interpretation of results *(5)*. Another consideration for interpretation criteria is the extent of normal variability between patients. Radiologists should familiarize themselves with a normal database *(2)*. General distribution of the radiotracer and symmetry between hemispheres should be observed.

Qualitative or semi-quantitative analysis can be done for brain imaging interpretation. PET/CT brain scans will differ for routine oncological PET/CT scan as a standard uptake value (SUV) is not used, however, a quantitative analysis can still be done. Absolute glucose metabolism can be done to calculate the arterial FDG concentration against time curve. This would require serial measurements of arterial blood sampling *(5)*. (Figure 5)

Semiquantitative analysis can compliment visual interpretation for DaTscans. To be interpretable, the semiquantitative data needs to be compared to a normal database for reference values *(2)*. However, the normal database will need further clarification in regards to what makes it “normal”. Not using an automated system for regions of interest (ROI’s) can cause interobserver variability. This can result in ROI placement errors and false interpretations can occur *(2)*. Automated ROI placement systems will help reduce that variability. Several different studies have been done that show t interpretations based on only semiquantitative information had good results in accurate diagnosis. However, this was only done with experienced readers *(2)*. There is no information on if inexperienced readers would have the same outcome but semiquantification information may benefit those readers with less experience *(2)*. (Figure 6)

Conclusion

Quality imaging starts at the technologist level. Understanding brain imaging and how to accomplish scans that results in high quality images is very achievable. Brain imaging is a critical part of the nuclear medicine field and when high quality images are obtained, it can help in the diagnosis of crucial conditions. Every step of the protocol should be followed, from patient preparation and education, patient positioning, camera operation and image interpretation. Images that are submitted for interpretation should be the best quality obtainable. This can mean having to overcome challenges that may be presented during the imaging process. If care and consideration are taken into understanding a protocol completely, these challenges can be alleviated and high quality images can be obtained.

Financial Disclosure: The author received no funding for this research

Acknowledgment: The author wishes to acknowledge Mary Beth Farrell for editorial assistance, mentorship and continued support.

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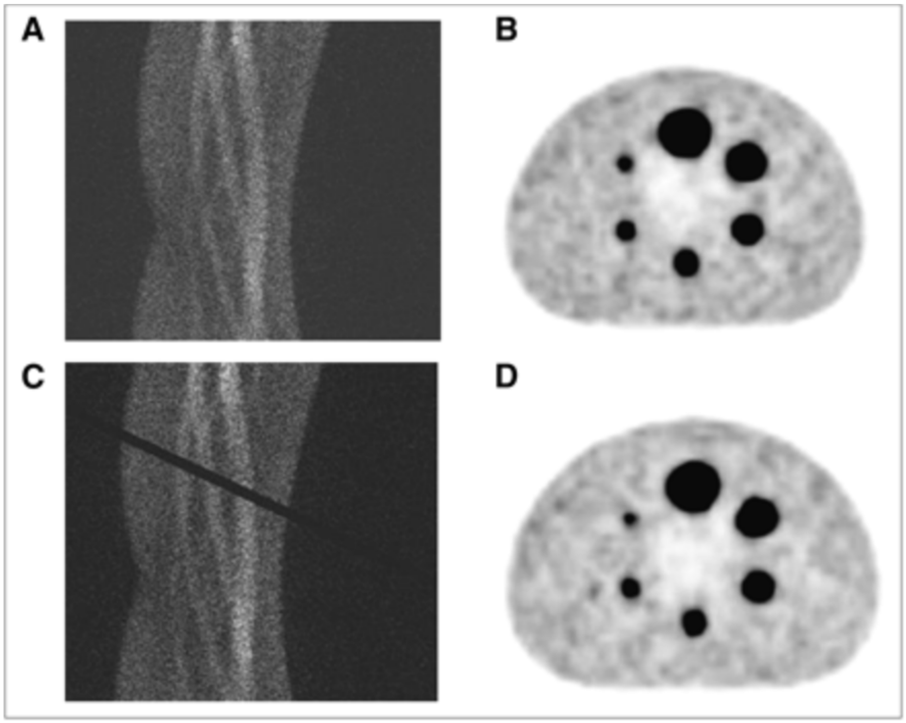


FIGURE 1: 18F-filled phantom. Two-dimensional PET sinograms. These images are reconstruction transverse images. Image (A) has a corresponding transverse image, (B). Image (C) which shows a diagonal black band, has the corresponding transverse image, (D). Even though you can see the black band in image (C) which can be suggestive of a faulty detector black, is virtually undetectable on the reconstructed transverse images, (B) and (D) *(11)*.

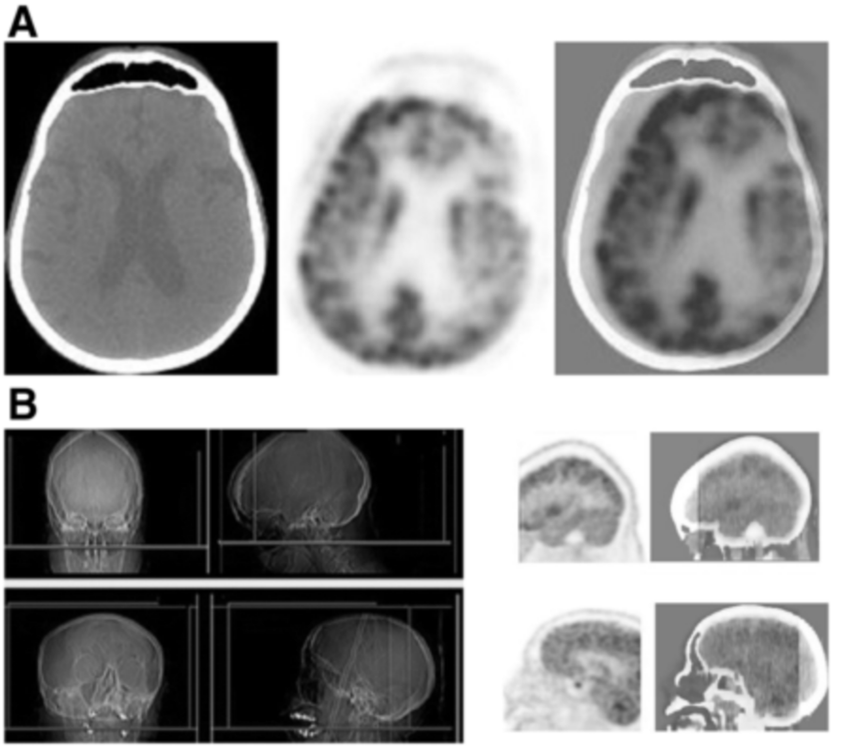


FIGURE 2: (A) 18F-FDG PET/CT images of the brain showcasing an excessive patient motion artifact. This artifact causes a false reduction in uptake in the left hemicortex. (B) Images show lateral x-ray scan and PET/CT images of the head. The views are transaxial and sagittal. This artifact is caused by a misplaced region-of-interest box on the scout images. This results in part of the brain being cut off in the final images. This is a technologist caused artifact *(12)*.

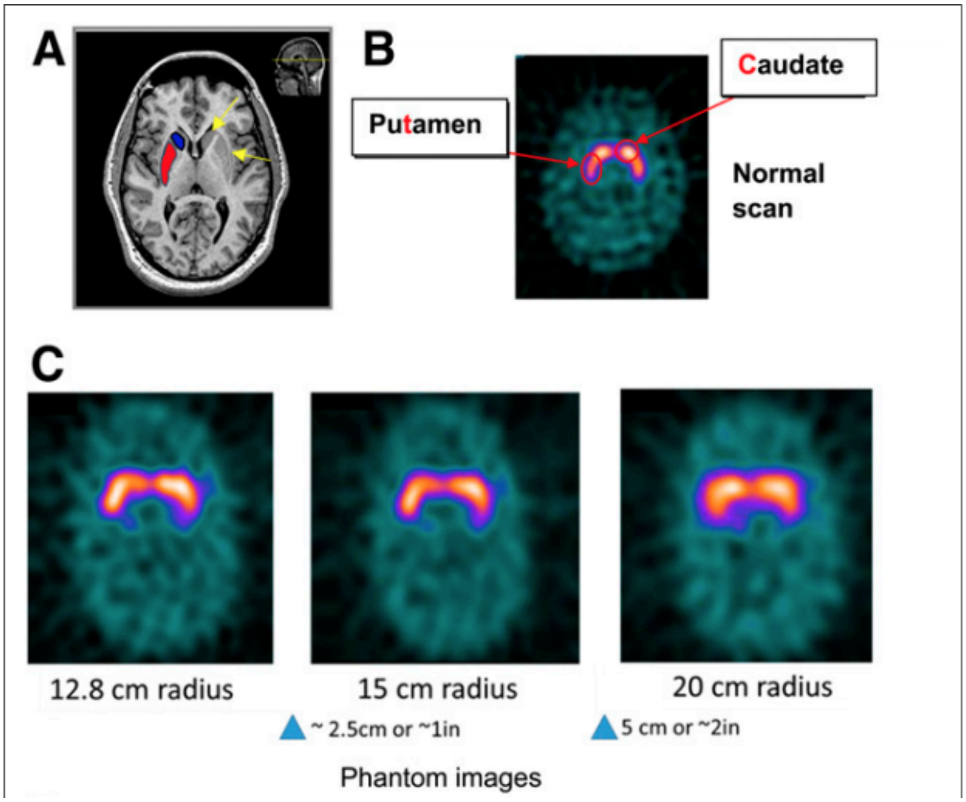


FIGURE 3: (A)(B) Caudate nucleus and putaman location within the brain. This is the main focus of a DaTscan and needs to be fully included in the images. (C) Showcases how important it is to keep the detector radius within the 11-15cm range. The more distance between patient and detector will increase blurring *(8)*.

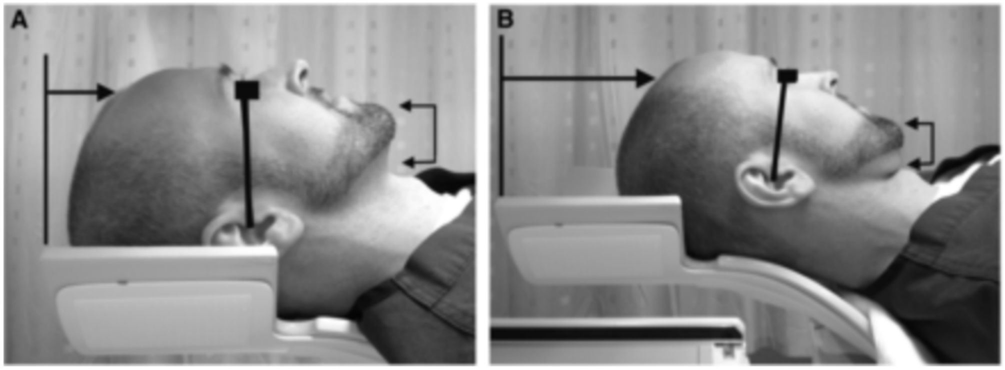


FIGURE 4: (A) Correct positioning of the head during brain imaging. Shows the invisible canthomeatal line that should be positioned as vertically to the imaging table as possible. This will help eliminate head tilt. (B) Incorrect head positioning. The patient's head is not fully placed in the head holder and creates more head tilt which can cause artifacts. The canthomeatal line is also not as vertical to the imaging table as it could be *(13)*.

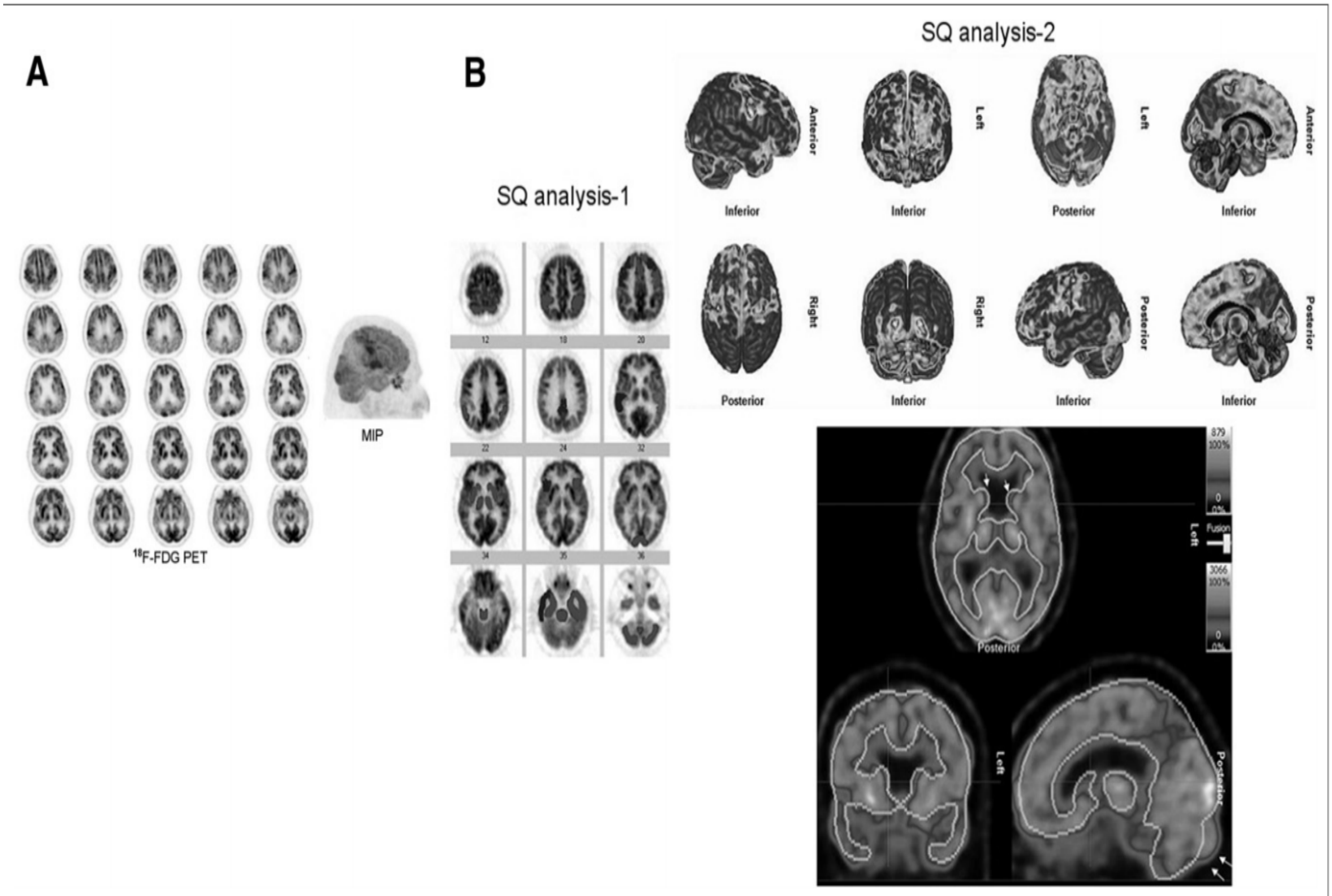
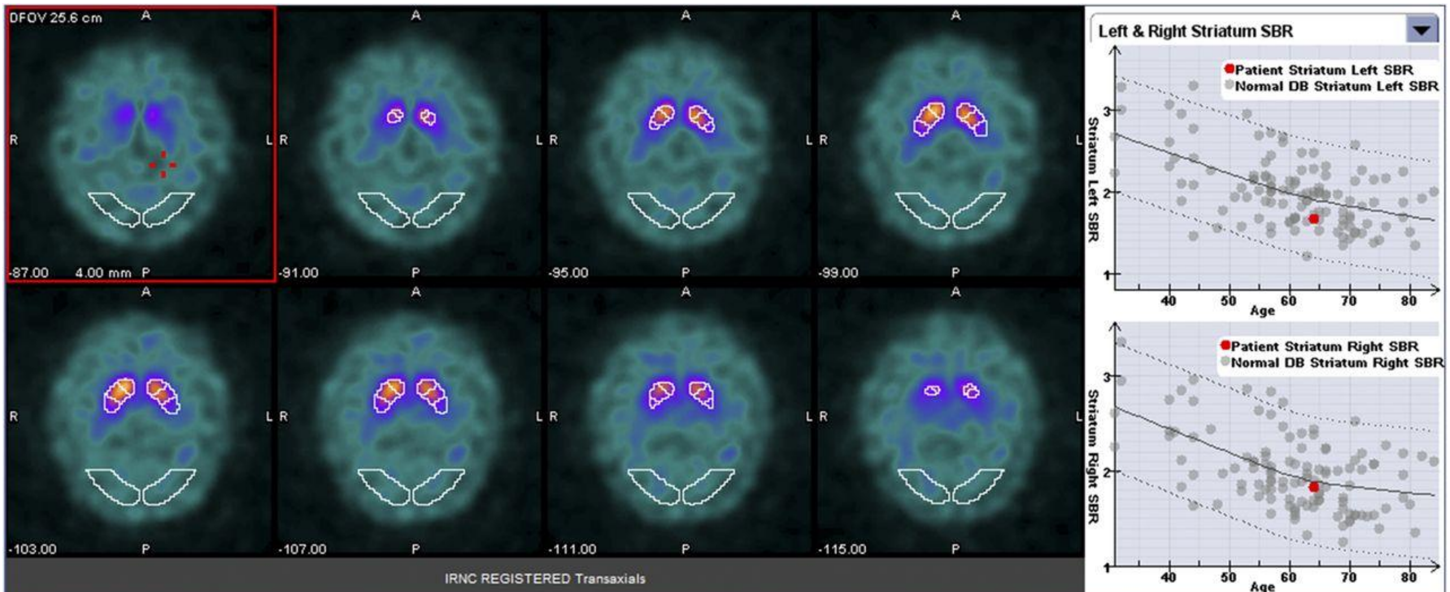


FIGURE 5: F-18 FDG PET brain images that show bilateral hypometabolism in the temporal and parietal lobes. It also shows bilateral mild hypometabolism in the frontal lobes. (B) Semiquantitative analysis also shows a reduction in metabolism in the patients frontal and temporal lobes as well as in the posterior cingulate cortices and temporoparietal junctions. The semiquantitative analysis, however, does not show hypometabolism in the patient's parietal lobes and undervalues the reduction of metabolism in the left temporal lobe *(12)*.



Normal DB: GE OSEM NC ...	Data:	IRNC	Gender:	Male	Counts(Counts):	2244499.0	Reconstruction: OSEM	Collimator: LEHR
GE normals database for ...	Camera:	IP2	Age(Years):	64	Dose(MBq):	185.0	Corrections: No Correction	Collimator: Parallel

	Striatum Right SBR	Striatum Left SBR	Putamen Right SBR	Putamen Left SBR	Caudatus Right SBR	Caudatus Left SBR
Measured	+1.83	+1.66	+1.69	+1.54	+2.14	+1.90
Mean (±1 SD)	+1.89 (±0.33)	+1.91 (±0.35)	+1.80 (±0.33)	+1.79 (±0.35)	+2.09 (±0.40)	+2.13 (±0.42)
Deviation	-3%	-13%	-6%	-14%	+2%	-11%
Z-Score	-0.19	-0.69	-0.34	-0.72	+0.12	-0.55

FIGURE 6: DaTQUANT is the semiquantitative analysis software used for DaTscans. The above figure shows how the results would be displayed with the ROI's placed *(14)*.