Impact of High Temperature and Humidity on the Performance of Positron Emission Tomography Scanner

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Abstract

Positron emission tomography/computed tomography (PET/CT) scanner is a state-of-art imaging device. Susceptibility of PET scanner in fluctuation environmental condition is known. Hence, every vendor prescribes the optimal conditions such as temperature and humidity to maintain the equipment in its best condition. In a hot summer day, we faced an unexpected long duration power failure in our department after administration of F-18 fluorodeoxyglucose to one of our patients. As air condition was not working in our department, temperature in the machine room went far beyond the prescribed level. As we had already injected the patient, we decided to perform PET scan of that patient in the existing condition in the machine room. When we reviewed the scan, we identified significant count loss in the image, which raised doubt in our mind. We discussed with our colleague and decided to perform a daily quality assurance (DQA) test to assess the condition of the equipment in high temperature. On DQA scan, we spotted several changes in the uniformity plot as well as energy plot. Following to that, the system was shut down completely till the main supply was restored successfully, and room temperature and humidity was restored to normal in machine room and console room. After several hours of restoration of normal condition in console and machine room, PET/CT equipment was restarted, and the DQA was repeated. On review, we found the restoration of normal DQA graph. We conclude that the sudden increase in temperature and humidity in PET/CT equipment room affects the performance of scanner which reflects as count deficit in the image. This impairment in the image quality may be because of bismuth germanate crystal, photomultiplier tubes, and associated electronics.

Keywords: *Artifact, bismuth germanate crystal, positron emission tomography/computed tomography, temperature*

Introduction

Positron emission tomography/computed tomography (PET/CT) scanner is a state-of-art imaging device used for imaging of various pathological conditions. Role of PET/CT imaging has been established in cancer imaging for staging of disease and monitoring of disease progression.[1] Diagnostic performance of PET scanner depends on the reliability of equipment in producing quality images.[2,3] Well-calibrated and maintained equipment is utmost important to produce the best quality of images. A battery of daily quality assurance (DQA) tests are prescribed by the vendor to assure the performance of equipment on daily basis.[3] DQA test is mandatory to perform every morning before starting the clinical study on the PET scanner.

PET/CT equipment is known to be susceptible to fluctuating temperature, electricity, and climatic condition in the equipment room; hence, maintenance of optimal condition is utmost important to maintain equipment in good condition.[2-4] As temperature and humidity plays a major role for the stability of crystal, photomultiplier tubes (PMTs), and other electronics, every vendor prescribes the optimal conditions such as temperature, humidity range, and maximum tolerable limit in the machine room.[4-6] Either of the parameters can lead to undue interruption in the functioning of the PET/CT. It is of prime importance for the end user to maintain the environmental condition in the machine room all the times and follow the instruction of the manufacturers properly. Second, as per company's set guidelines, the ambient atmosphere is maintained to obtain optimum results from the modality and avoid any major breakdown. Such

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events of breakdown can lead to cancellation of patients' study and also increase the radiation burden of patients in case of failure being diagnosed after injecting the patients.

Case Report

Our institute being in rural area does face problem with power cut, and as a mandate, we do have provision of battery backup/generator supply to power the PET/CT equipment for scanning purposes. However, we do not have air-conditioned backup in the machine and console room. We schedule our patient considering these conditions and perform the scan. In a hot summer day, we encountered an unusual scenario of power cut in our area for several hours. We had one patient waiting in the patient waiting room for the scan who was injected before the power cut. We were waiting for electricity supply to be restored, but when power supply was not restored for one long hour, we decided to perform PET scan on emergency supply. While the PET/CT acquisition was going on, we could see very few photon counts in the gantry display system in spite of progress of study. The acquired data after successful completion of the study were reconstructed and an image generated. We observed significant low counts in PET images in comparison with routinely performed scan [Figure 1a-d]. We discussed this with our colleague and everyone identified count loss and anticipated this count loss due to some malfunctions of equipment. To investigate the cause of this count loss, we physically inspected the bore of the gantry first and further decided to perform the DQA test to assess the performance of the PET scanner. The DQA test graph was analyzed by two nuclear medicine physicists in the department. Both the physicists interpreted the nonuniformity in coincidence, singles, and timing graph generated by DQA scan [Figure 2a]. We registered a call for GE service support; fortunately, engineer was working at a nearby site and arrived to our center in half an hour. He also agreed to our observation and started finding out possible reason behind this defect. When he entered in machine room and observed that temperature in machine room was around 29°C and humidity was around 76% which was quite high in comparison of routinely maintained temperature and humidity 20°C ± 2°C and 45% ± 5%, respectively. Service engineer immediately opened up the external covers of the PET/CT gantry and evaluated the damage of any part of hardware system and associated electronics. He also ran the check on acquisition console for electronic failure. System passed all the checks except temperature. Finally, he checked the graph of the PET/CT system temperature indicator for the past few hours and it was quite high for the last few hours. After detailed discussion with service engineers, we suspected that the high temperature and humidity are the cause of count deficiency in the clinical image and abnormalities in DQA graph. We decided to shut down the equipment till normal temperature and humidity is restored. After 2 days, we were able to restore normal temperature and humidity. Service engineer performed electronic and temperature check after 56 h of restoration of normalcy in climatic condition inside the gantry room, which was found to be normal. Subsequently, we performed DQA test. On review by service engineer and physicist in the department, DQA found to be normal [Figure 2b]. Upon complete satisfaction, we procured F-18 fluorodeoxyglucose and performed clinical scan [Figure 1e-h]. Clinical scan was reviewed by nuclear medicine physician, service engineer, and physicist. Moreover, all of them reached on conclusion that the image quality of clinical scan was satisfactory and reportable. We accepted the PET/CT equipment for clinical use upon satisfaction.

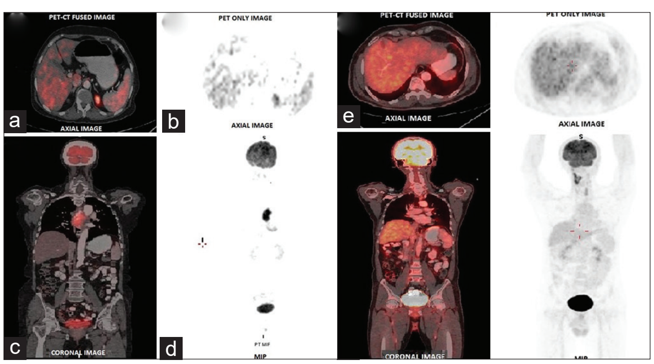

Figure 1: Postbreakdown clinical positron emission tomography/computed tomography image (activity = 9.3 mCi; Scan time = 90 min) shows count deficiency in transaxial positron emission tomography/computed tomography fused image (a), transaxial positron emission tomography image (b), coronal positron emission tomography/computed tomography fused image (c), maximum intensity projection image (d). Postrepair clinical positron emission tomography/computed tomography image (activity = 8.1 mCi; Scan time = 70 min) shows normal counts in transaxial positron emission tomography/computed tomography fused image (e), transaxial positron emission tomography image (f), coronal positron emission tomography/computed tomography fused image (g), Maximum intensity projection image (h)

Discussion

Bismuth germanate (BGO) is a hard, rugged, and

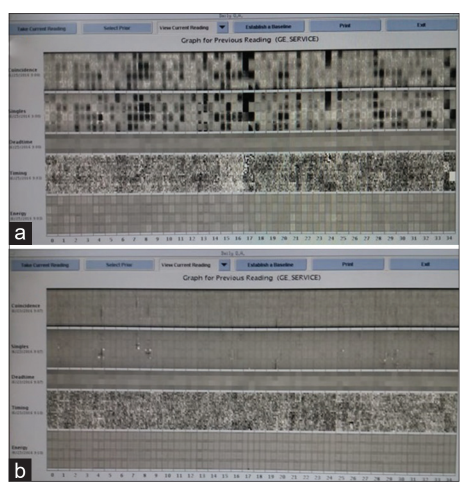

Figure 2: Postbreakdown daily quality assurance graph shows patchy defects in coincidence, singles, timing, and energy graph (a) and postrepair daily quality assurance graph shows normal graph (b)

nonhygroscopic crystal, which can be machined to various shapes and sizes. BGO is characterized by high radiation hardness, absence of afterglow, good light output and energy resolution, and amply good decay time.[4-7] These qualities of BGO crystal make it as good candidate to become scintillation crystal for PET scanner. Second, the intrinsic 300 ns luminescence of Bi^{3+} ions (3P11S0) at 480 nm wavelength gives excellent current output with PMT. Being a pure crystal, it eliminates the problems with nonuniform distribution of luminescence centers, prevalent in doped crystals such as NaI (Tl) crystal.[8] However, despite having several favorable qualities, major drawback of BGO crystal is temperature dependence. Slight increase in temperature of BGO crystal reduces light yield significantly.[9] The PMT is also known to be susceptible with temperature and humidity. The steep decrease in temperature is known to cause reduction in dark current of photo cathode where as steep increase in temperature is known to cause current saturation in PMT. Rise in temperature is also known to reduce the overall output of PMT.[10] The PMT is recommended to be used below 60% of humidity level.[11] PET electronics are also recommended to be used in optimal level of temperature and humidity. In our case, we observed the grossly reduced counts in PET images, despite optimal injected activity and imaging time. Our finding of count loss in PET clinical images was also supported by DQA graph that was due to problem in PET/CT equipment. Since, all the parts and electronics were working and only increase in temperature and humidity had led to the count deficiency in the PET images. Since, significant increase in temperature and humidity, i.e., 10°C and 25%, respectively, was noted on that day during the PET scan, the significant decrease in counts and severe defects in DQA graph may be attributed to rise in temperature and humidity in the gantry room. Although the light output of BGO crystal decreases tremendously due to 10° rise in temperature,[6-9] the reduction in count cannot be attributed to the crystal alone because PMT and associated electronics are also known to behave erroneously due to increase in temperature and humidity.[10,11] In our case, we were able to identify the defects due to huge rise in temperature and humidity in gantry room, but there might be reduction in count rate performance in few degree rise in temperature which needs to be taken care of while we are operating such a sensitive equipment. As we saw in our case if climatic condition is not maintained properly throughout, PET scanner may start performing erroneously despite passing on all the parameters in DQA test at the beginning of the day.

Conclusion

Our case report suggests that the maintenance of optimal climatic conditions such as optimal temperature and humidity throughout is utmost important for optimal performance of equipment. Sudden change in temperature and humidity should not be ignored, and appropriateness of image quality should be checked by performing DQA test.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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