Challenges in Accessing and Operating PET-CT: Patient Experiences and Institutional Hurdles in a Newly Established Nuclear Medicine Institute in Bangladesh

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ABSTRACT

Positron Emission Tomography-Computed Tomography (PET-CT) is one of the latest state-of-the-art hybrid imaging techniques of nuclear medicine that has various applications in oncology, neurology, cardiology, and infectious disease evaluation. However, accessing this facility in Bangladesh and other 3rd world countries remains limited mostly due to financial barriers. Limited infrastructure, radiopharmaceutical unavailability, and lack of skilled and trained personnel are also some major obstacles of accessing PET-CT in this country. The difficulties patients and nuclear medicine staff encounter while trying to obtain and use ^{18}FFDG PET-CT services in a newly established institute like Institute of Nuclear Medicine and Allied Sciences (INMAS), Suhrawardy along with some scenario-based operational challenges have been highlighted in this context.

Keywords: PET-CT, hybrid imaging, operational challenge, ^{18}FFDG, radiopharmaceutical

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INTRODUCTION

Positron Emission Tomography - Computed Tomography (PET-CT) is a hybrid imaging technique that serves as a powerful diagnostic tool for a wide range of medical fields like oncology (cancer detection and staging), cardiology (i.e., assessment of cardiac function, myocardial viability, and cardiac inflammation), neurology (i.e., brain disorders, Alzheimer’s disease, Parkinson’s disease, and epilepsy), infectious disease, and assessment of therapeutic responses (1).

The total procedure of a whole-body PET-CT consists of several steps. Patients need to provide thorough clinical history to nuclear medicine physicians. Patients must fast for 4-6 hours before undergoing a scan and then receive the appropriate radiotracer, like 18F-fluorodeoxyglucose (FDG) for a whole-body PET-CT scan. Patients rest absolutely for 40-80 minutes after the injection and before scanning starts. The ideal uptake period for a whole-body FDG PET-CT scan is 60 minutes, which is termed as the “metabolic uptake period” (2). Consecutively, non-contrast CT, contrast-enhanced CT (CECT), and PET acquisitions are performed in a row. The posture of the hands, staying motionless and avoiding needless movements, and how to breathe throughout the scan period are some additional important aspects that the patients are practically briefed on during each PET-CT scan (3, 4).

^{18}F-FDG is a positron-emitting radiotracer. The PET camera detector picks up gamma rays that are released from the body as a result of positron annihilation. FDG accumulates in the metabolically active tissues throughout the metabolic uptake phase following radiotracer injection, making it possible to identify aberrant activity in any tissue. The CT counterparts use X-ray to visualize detailed anatomical images of the body. These two images combine to form a 3D fused image by one of the image registration software’s of different vendors like Limbus AI Inc., Syngo.via, Mirada Medical Ltd., etc. (5).

Cutting-edge PET-CT systems, like the Biograph mCT of Siemens, combine with innovations such as artificial intelligence (AI)-based deep learning (DL) algorithms for image reconstruction, noise reduction, and artifact correction. It addresses challenges like motion artifacts and improving overall image quality. Moreover, quality control processes, including detector calibration, collimator performance checks, and image alignment verification, are essential for maintaining system accuracy and reliability (6).

Despite advancements in imaging technologies, healthcare services in third world countries like Bangladesh face significant obstacles in accessing these facilities. Economic, availability, and manpower constraints are the main issues that people in third-world countries deal with. For a cancer patient, there are many other expenses that must be paid in addition to the price of PET-CT (7). Another issue is the availability of cyclotrons. Bangladesh has 15 PET-CT scanners, but only two cyclotrons are available, limiting the capacity for diagnosis and research in the country. This number is not sufficient to operate all the PET-CT scanners for diagnosis as well as research (8, 9). The primary challenges and limitations faced during the routine performances of PET-CT imaging and how these were overcome are discussed in this context.

STUDY DESIGN AND METHODOLOGY

An observational and situational analysis of the exploration of the challenges faced by both the general public (patients) and nuclear medicine (NM) personnel while performing PET-CT in a newly established institute at Dhaka, Bangladesh. The study focused on the operational difficulties a NM institute had when operating a PET-CT scanner as well as patient-related hurdles to accessing PET-CT services. The observational data was collected from various reliable online sources, i.e., the World Health Organization (WHO), International Atomic Energy Agency (IAEA), World Bank Economic Data, and authentic health-related websites of different countries. The situational data was gathered from different scenarios authors faced practically during the operation of the PET-CT scan at INMAS, Suhrawardy.

Instrument: A new state-of-the-art Siemens Biograph mCT PET-CT scanner was installed at INMAS, Suhrawardy, in February 2024. The Biograph mCT scanner is well known for its image quality, speed, and efficiency. Detector type is Lutetium Orthosilicate (LSO) with crystal size having Time of Flight (TOF) capability. The axial field of view (FOV) is 21.0 cm, which is ideal for whole-body scanning. CT counterpart has a stellar detector along with diamond-shaped scintillators, ensuring high resolution and 256 slices, allowing high-speed scanning.

Patient preparations: The whole-body F18FDG PET-CT of the patients was performed after at least 5 hours of fasting and a 50-minute metabolic uptake period. A non-contrast CT and mostly a contrast-enhanced CT (CECT) were performed before the PET scan. The PET scan was performed 1.2 minutes per bed position. After scanning, the image was fused and reconstructed to produce combined PET-CT images.

RESULTS AND DISCUSSION

1. The Patient’s Perspective: Challenges in Accessing PET-CT

Financial Constraints: Significant hurdles are faced in implementing molecular imaging technology because of the generally inadequate healthcare budget, which disproportionately affects the NM sector, mostly due to inadequate funding. One of the most expensive tests offered by the NM department, PET-CT is difficult for low-income individuals to afford. The initial instrumentation is expensive, often costing millions of dollars for the providers. This upfront cost is the major barrier to expanding modern NM imaging facilities for a developing country with a low healthcare budget. There are substantial and continuous maintenance expenses even after acquiring a PET-CT system.

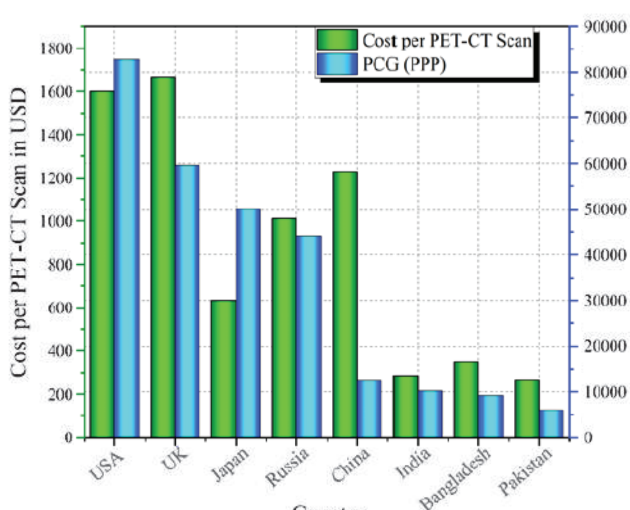

Figure 1: Graphical Representation of Cost of PET-CT scan and Per Capita GDP on the basis of Purchasing power parity in Different countries

Bangladesh Atomic Energy Commission (BAEC) has been solely operating all of the country's government-owned PET-CT facilities since 2014. The rate of whole-body ^{18}F FDG PET-CT in government-funded PET-CT is 25,000 BDT (approx. 204 USD); the other non-government rate is ranging from 40,000 BDT to 65,000 BDT (326.46 USD to 530.49 USD). The cost per PET-CT scan and per capita GDP according to Purchasing Power Parity (PCG PPP) of three South Asian countries are graphically represented in Figure 1, comparing them with five first-world countries according to the World Development Report of the World Bank (10).

Lack of insurance coverage: Lack of health insurance in Bangladesh significantly hampers access to advanced medical imaging technologies such as PET-CT. According to the report of a2i (government program of ICT division), only 2.5% of the total population of Bangladesh is under the coverage of health insurance, and the remaining are vulnerable to the high expenditure of the healthcare sector of Bangladesh. On the other hand, the USA covers 92.3% of the population under health insurance (11).

2. Infrastructure Perspective: Challenges in operation

Radiopharmaceutical production: PET-CT scans require the use of radiopharmaceuticals, which are produced in highly specialized and secured cyclotron facilities. Establishing the infrastructure with maintenance and operating the cyclotron facilities is not only costly but also demands high expertise for producing radiopharmaceuticals. Many countries lack the infrastructure and expertise and depend on imports, which might be costly, unreliable, and interrupted. A variety of PET radiotracers have diverse applications, such as ^{18}F-FDG, 68Ga-EDTA, 11C-O-methyl-glucose, etc. (12).

Training and personnel costs: Operating a PET CT scanner requires a team of highly trained professionals, including NM physicians, radiologists, physicists, and NM technologists. Training individuals can be costly and time-consuming, and retaining qualified personnel in a particular institute might be more difficult due to a lack of manpower in most of the NM institutes under BAEC. Hands-on clinical and technical training and workshops on PET-CT have limited availability. On the other hand, foreign training on PET-CT is presently discouraged due to a lack of USD reserves, which limits the growth of skilled and trained personnel, hampering the smooth operation of PET-CT.

Limitations of infrastructure: Uninterrupted power supply and stable internet connectivity are essential for the operation and maintenance of PET-CT scanners. Struggling with the disruptions limits delivery of healthcare services.

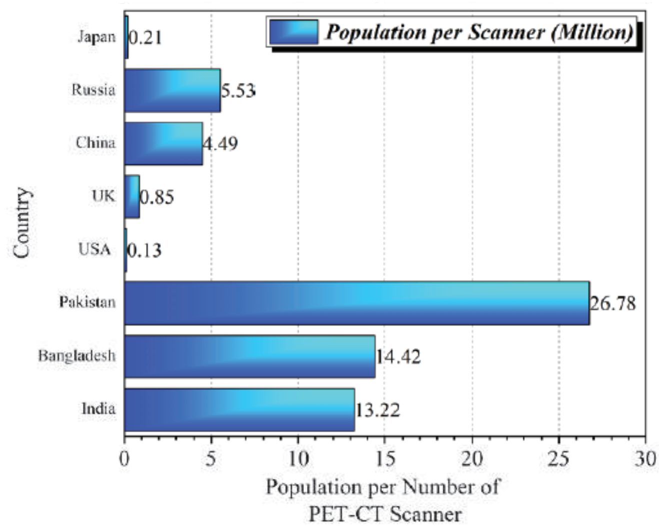

Figure 2: The Number of population per unit PET-CT Scanner in different countries

Bar charts in Figure 2 show the country-wise ratio of the number of populations to the number of PET-CT facilities. There is one PET-CT scanner for every 14.42 million persons in Bangladesh. However, the worth is less than half a million dollars for the USA.

3. R & D Perspective: Skilled manpower development

Limitations of research and development: Dedicated PET-CT scanners for biomedical imaging facilities are found in industrialized nations to enhance research and development of medical physics, imaging, and education in the field of NM. Whereas the PET-CT facilities are overburdened with routine services for critical patients and offering negligible time and openings to research.

4. Operating PET-CT at INMAS, Suhrawardy: Challenges in patient services

Scenario 1: A 70-year-old patient with decompensated CLD and plasmacytoma became unconscious during a whole-body 18F-FDG PET-CT at INMAS, Suhrawardy. The oncologist advised immediate PET-CT for accurate treatment planning. Due to drowsiness, the patient was infused with intravenous 0.9% normal saline. Despite drowsiness, excessive movement produced motion artifact, which is visualized as the distorted image in the abdominal area (Figure 1a).

Scenario 2: An 11-year-old boy with a history of intra-abdominal alveolar rhabdomyosarcoma underwent whole-body ^{18}F-FDG PET-CT for disease evaluation after 3 months of 10 cycles of chemotherapy. During the post-injection waiting period, he started vomiting several times. Waiting for an extended time and antiemetic could not rescue the scan, as the patient vomited in the middle of CT and PET acquisition, which led to serious misregistration of the fused PET-CT images shown by white arrows (Figure 1b).

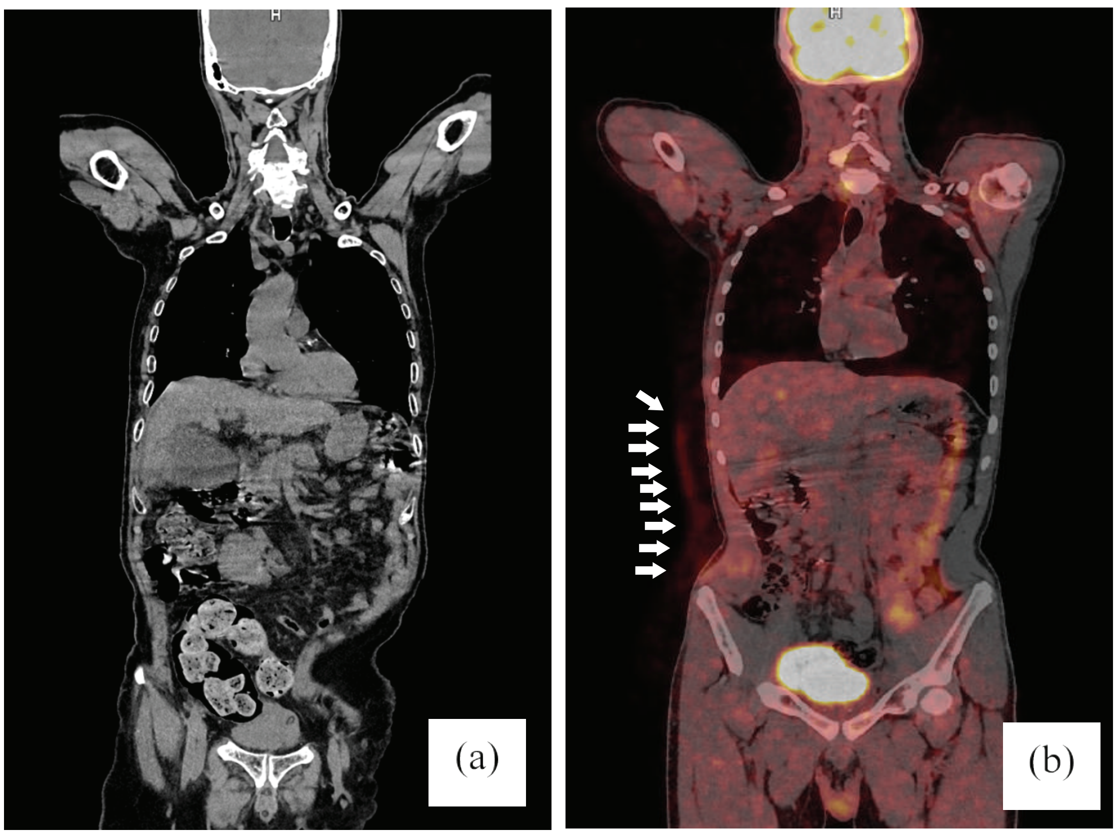

Figure 1: (a) CT image of a 70-year-old male patient with motion artifact, (b) Fused image of a 11-year-old pediatric patient with misregistration

Scenario 3: A 39-year-old woman with a history of carcinoma of the appendix was requested to have a whole-body ^{18}F-FDG PET-CT immediately after receiving 8 cycles of chemotherapy. The patient's thin veins made it challenging to cannulate. Eventually, the patient started showing anxiety with rapid and fast breathing, non-cooperation, and threatening to postpone the scan immediately, which was unacceptable to the scanning team, causing a tense situation. Ultimately, the image quality was affected, and there was an unwanted delay in the scan.

Scenario 4: Due to technical difficulties with the X-ray tube of the PET-CT scanner, the must-performed daily checkup failed in a government NM institute in November, 2024. But the patients were already on a metabolic uptake period after dose administration and cannot be rescheduled. The patients were sent to INMAS, Suhrawardy, for a PET-CT scan immediately on that day, and we completed the scan without any complications. By changing the X-ray tube, the PET-CT scanner of that NM institute was ready after 2 days. It is hard to get instant technical support in Bangladesh due to a lack of technical experts.

Scenario 5: A 63-year-old woman with a history of right forearm leiomyosarcoma had a whole-body ^{18}F-FDG PET-CT, but severe cough during CT acquisition caused misregistration artifact in the chest area. Almost 50% of the heart was misplaced during fusion, which is shown in Figure 4a.

Scenario 6: A 58-year-old woman with a clinical history of carcinoma of the right lung had a whole-body PET-CT scan. After dose administration, excessive movement and not following the commands caused leakage of her cannula, causing contamination (Figure 4b).

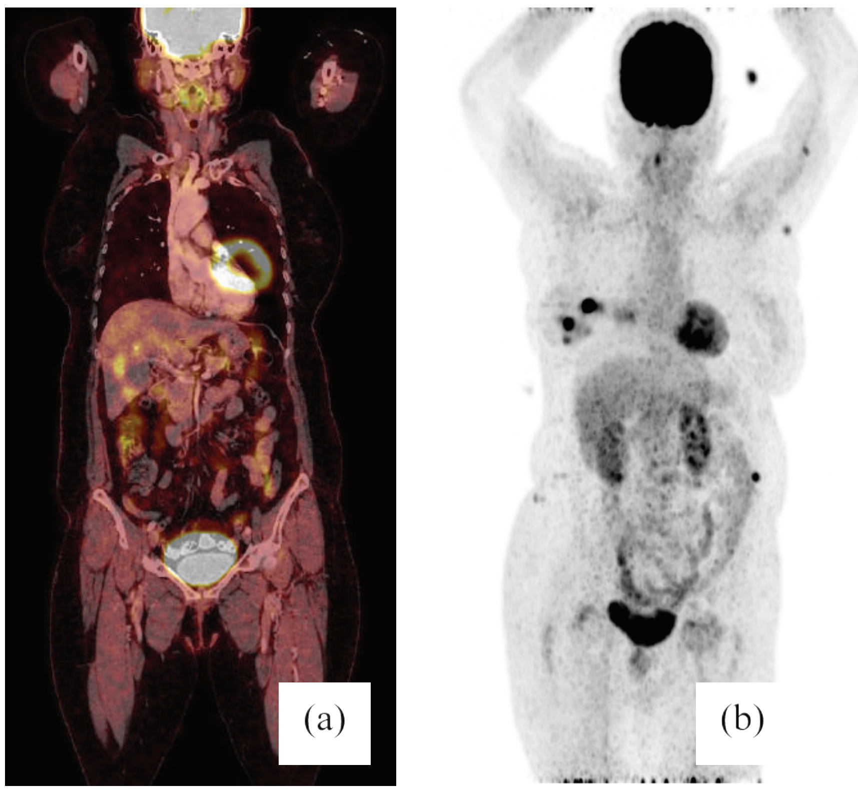

Figure 4: (a) Fused image of a 63-year-old female patent having respiratory motion artifact, (b) FDG contamination detected in a PET image of 58-year-old woman

Scenario 7: A 50-year-old woman with a history of carcinoma of the sigmoid colon had a whole-body PET-CT scan in INMAS, Suhrawardy. The patient experienced severe discomfort during intravenous contrast injection by an auto injector, causing displacement of the cannula and resulting in no contrast delivery. Contrast accumulated under the dorsal surface of the skin of the right hand. As the patient was a diagnosed case of sigmoid colon cancer, oral contrast was administered promptly, which helped the physician to visualize gut pathology, but due to a lack of IV contrast agent, lymph node assessment was suboptimal.

Scenario 8: During PET-CT scanning in the NM department of a private hospital, the patient bed was stuck during imaging. It was because of the mechanical failure or a software glitch. They were unable to solve it immediately. The PET-CT team of INMAS, Suhrawardy, extended support instantly and smoothly scanned the rest of the injected patients in waiting by promptly transporting them to this building. Though slight, the delay in scan affected the image quality.

PET-CT scan is crucial for successful diagnosis, requiring patient counseling on fasting, resting, breathing protocol, and radiation safety. Post-processing can minimize artifacts by using respiratory gating devices and correcting filtering and attenuation correction.

CONCLUSION

Accessing and operating PET-CT scan facilities, especially in developing countries like Bangladesh, is challenging due to financial constraints, high equipment costs, maintenance costs, and lack of radiopharmaceuticals. Limited infrastructure, communication, internet connectivity, and lack of trained personnel further complicate the accessibility. Technical difficulties and misregistration artifacts also impact image quality, which often remains beyond the level of correction even after sincere efforts of the whole team. Careful patient preparation, such as pre-scan counseling, proper positioning, and continuous monitoring, can help mitigate these challenges. Implementing strategies like respiratory gating devices, advanced image reconstruction algorithms, and regular equipment maintenance can improve PET-CT imaging outcomes and patient care.

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