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# PET/CT Imaging: Maximum Utilization at Lowest Time Consumption

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**Abstract**

Positron emission tomography (PET) and computed tomography (CT) combination is the most recent medical imaging technique that uses small quantities of a radioactive tracer called flurodeoxyglucose ($FDG^{18}F$), to produce images showing how our body is functioning. Different professional experts are engaged to perform the sophisticated PET/CT imaging system and take considerable time. The work is dedicated to optimize the use of whole PET/CT imaging system to minimize the time consumption from patients profile registration to CT study. Data from 1 January to 31 January 2014 and from 1 July to 31 July 2014 were recorded, represented as 1st month and 2nd month respectively, measuring the time required by every step of the patient's pathway. The data of the first month acquisition shows that, five patients were examined through this arrangement in a single day. By reducing patient turnover time and consequently the device downtime, patient turnover time dropped from 5 minutes to only 3 minutes while device downtime devolved from 90 minutes to 70 minutes between the first month and the second month data acquisition. Hence the number of daily performed examinations increased by two. Continuous activity control allow the identification of critical organizational and structural issues; provide us useful information to the optimization in the use of expensive and sophisticated PET/CT devices with a clear value in public health, great benefits for the patients and improved management results.

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***Keywords:*** PET/CT; Flurodeoxyglucose- $^{18}$F; Image; Time consumption; Cost-Effectiveness; Acquisition protocol.

## 1. Introduction

Positron emission tomography (PET) is a power full medical imaging technique which produces a three-dimensional image of functional processes of organs in the body. This functional imaging technique has been used for the last few decades in many clinical applications [1-2]. It is also uses in monitoring response after therapy [3] in the study of new pharmaceutical drugs [4], and in studying engineering processes [5]. The latest generation of PET scanner incorporated a computed tomography (CT) scanner to provide accurate anatomical images, and the integrated system is known as PET/CT, which has been used in many clinical applications [6-7]. In this work, we employed this imaging technology in cancer treatment and for its early staging [8]. The highest possible number of image scanning during the operational hours of PET/CT device depends on combination of the device's operational hours and the acquisition protocol, which reduce the waiting list of patients and increase the efficiency of resource management system [9-12]. The objectives of this investigation were to analyze of the whole PET/CT imaging protocol from the registration of patient to the end of the test, paying particular attention to the time required for every step of the process, the number of examined patients and their stay in the department. We also analyzed critical points of the process to provide information of general interest.

## 2. Materials and method

### *2.1. PET/CT Centre*

PET/CT is operational two days in a week, Saturday and Tuesday: From 9 a.m. to 5 p.m. During operative hours, hospital representatives devoted to patient registration, a nuclear physicist, a physician, a radiologist, a nurse and a radiologic technician are present in the department. Flurodeoxyglucose (FDG-$^{18}$F), the radio pharmaceuticals produced by a cyclotron in the hospital hosting the PET/CT centre. A particular quantity of FDG-$^{18}$F is prepared once in a day depending on the number of patients.

### *2.2. Pathway of the patient*

After appointment, the patient is interviewed by a physician to receive information about medical history of patients, to verify the indications for the test and ask for a written consent. Glucose test is mandatory for all patients which is performed by a nurse. If all results are within normal range of values, the physician injects a tracer of FDG-$^{18}$F into a vein usually in the arms. After receiving the tracer (FDG-$^{18}$F), patients need rest and remain silently lying down for approximately 1hour while the injection is absorbed into the body. If blood glucose level is higher than normal ones, the patient is asked to take a walk for 10-15 minutes and a further glucose test is performed. In the rare cases in which blood glucose level does not reach acceptable values, the exam is postponed. If the glucose test within normal range, then the patient is taken to a quiet and dimly lit room, isolated from the rest of the department, in which he is administered intravenous saline and oral contrast medium in order to highlight the bowel during the CT scan. FDG-$^{18}$F uptake requires 45-60 minutes, after that the patient is requested to void the bladder, subsequently positioned into the PET/CT device by the radiologic

technician and, upon the radiologist's indication, connected to the contrast fluid delivery system. A CT scan is executed to provide attenuation correction for the subsequent PET scan and anatomic localization of FDG-$^{18}$F uptakes. Through the annihilation process, electron coming from our body and positron from the isotope FDG-$^{18}$F combine together and produce gamma rays. Gamma rays are detected through the detector and electronics configuration construct images. Then quality of the acquired images is evaluated and, when indicated, a second CT scan is performed with the use of contrast media injected by the radiologist. Developed images sent to an imaging workstation and jointly evaluated by the nuclear medicine physician and the radiologist who produce together a single medical report including morphologic, metabolic and functional information, and diagnostic conclusions. Significant pathological outcomes are printed as images and meanwhile the radiologic technician burns a CD containing the complete exam, which will be given with the report.

### *2.3. Various factors contributing in the Patient Pathway's in PET/CT management*

**Table 1:** The factors influencing the examination process

| | **Patient** | **Setting** | **Process** | **Device** | **Organization** | **Management** |
|---|---|---|---|---|---|---|
| **Most Important** | Age<br>Availability<br>Punctuality | Communication<br>Paths<br>Patient flow<br>Waiting room | Exam complexity<br>Defined processes | FDG-$^{18}$F | Communication<br>Physician availability | Schedule compliance<br>Communication |
| **Very Important** | Emotivity<br>Mobility | Distance<br>Room location | Defined protocols | | Registration access<br>Technologist availability<br>Nurse availability motivation | Registration process<br>Internal disturbance factors<br>External disturbance factors |
| **Important** | Weight<br>Sex | Room access | Exam methodology | | | Emergency |

Table 1 exhibits that PET/CT patient scanning execution process depends on some relatively weighted variables. Weights represent the contribution of each factor in PET/CT execution process. In this arrangement, all weights, classified into "important", "very important" and "most important", are crucial factors for fruitful execution. As evidenced, considering the patient availability organized into a waiting list, and radioactivity of FDG-$^{18}$F, nuclear physicians and radiologists, the most important factors are patient punctuality, a space arrangement facilitating the patient pathway and the avoidance of eventual interferences with exam planning by emergencies.

All data was accumulated, focusing on the most important elements in the PET/CT center's organization and administering a checklist on such topics to patients, physicians, nurses and admitting representatives.

### *2.4. Data assembling*

We analyzed two periods of data: the first period from 1 January to 31 January 2014 and the second period from 1 July to 31 July 2014 represent as 1st moth and 2nd month respectively. During these periods questionnaires were administered in the PET/CT center of the diagnostic imaging department required administrative staff, nurses, radiologic technicians and physicians. Arrangement and out of it for two different periods of time.

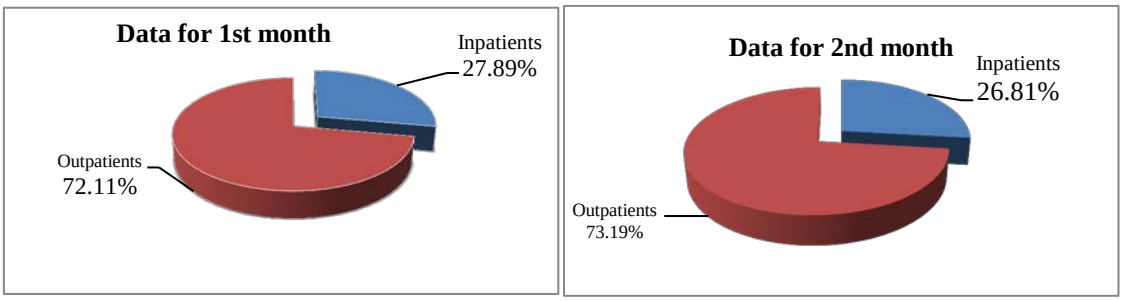


**Figure 1:** This illustration exhibits total time distribution within the PET/CT

The time required from registration to the end of the investigation for each and every step of the patient pathway was evaluated. Though the highest number of study held in the PET/CT center was 7, we investigated only 5 exams a day after the first data acquisition. Figure 1 shows the ratio of the outpatient/inpatient between the two data acquisition periods.

## 3. Results

The observed data of the first and 2nd month's acquisition is shown in Table 2, where 5 patients were examined. The device downtime and patient turnover time was recorded and analyzed.

We might maximize the use of this machine by reducing patient turnover time and the device downtime for better organization of PET/CT. The comparison between 1st month and 2nd month's data collection shows that, patient turnover time reduced from 5 minutes to 3 minutes and the downtime of the device decreased by 20 minutes.

Therefore, the number of investigated patients was increased from 5 to 7 i.e. 40% more patients can be examined in the same time with the same resources.

**Table 2:** Data acquisition in different periods.

| Types | 1st month | 2nd month |
|---|---|---|
| Patients per day | 5 | 7 |
| Average device downtime | 90 minutes | 70 minutes |
| Device usages | 80.2% | 86.7% |
| Average turnover time | 5 minutes | 3 minutes |

**Table 3:** Total Investigations time

| | Required time in minutes | |
|---|---|---|
| **Types** | **1st month** | **2nd month** |
| Study length from patient arrival | 138 | 126.7 |
| Study length from schedule time | 134 | 122.9 |

Total investigation time of two different periods is shown in Table 3. The average time execution for the first month was recorded 138 minutes while that of the 2nd months was 126.7 minutes.

Analyzing data from Table 4 and Figure 2, the second collection period, total execution time was evaluated from the patients scheduled appointment time. In this way the total required time decreased.

The variation of patient's arrival time causes a high deviation.

All patients were not punctual enough in both examination processes; most patients arriving early in the first data acquisition period while a very high rate of patients arrived late during the second one.

**Table 4:** PET/CT examination steps with duration.

| Steps | Required time in minutes | |
|---|---|---|
| | **1st month** | **2nd month** |
| **Profile registration** | 4 | 3.8 |
| **Waiting for meeting** | 9.5 | 5.7 |
| **Meeting** | 9 | 10 |
| **Required time for glucose test** | 25.2 | 23.5 |
| **FDG administration waiting time** | 47.3 | 45 |
| **Patient preparation** | 4.5 | 4.7 |
| **Standard PET study** | 26 | 26 |
| **CT study** | 12.5 | 8 |
| **Total** | 138 | 126.7 |

During the second data period, comparatively 5% of the patients increased from the first data period because of faster profile registration. Waiting time for the meeting with physician was 9.5 minutes for first data period is decreased by 3.8 min in the case of second data period, for these reason 40% patients increased significantly during analyzing data from the second collection period.

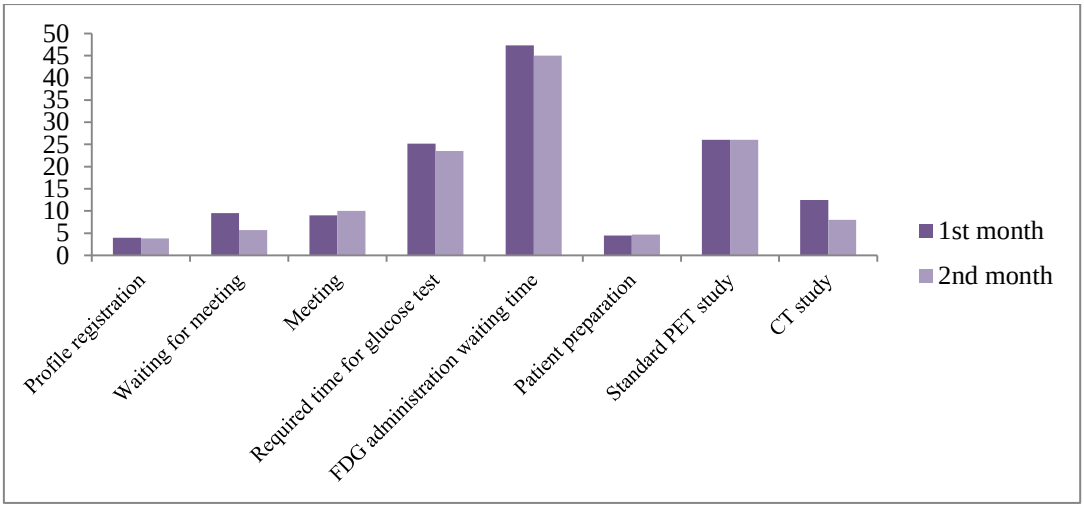


**Figure 2:** Comparison of PET/CT Examination Steps with duration for two acquisitions

Glucose test waiting time had a 18% influence on the overall PET/CT examination time in the second data collection period compared to a 18.65% influence in the first one seems almost same. FDG- $^{18}F$ administration waiting time had a 34% influence on the overall study time in the second data collection period compared to a 35.5% influence in the first one, though almost 5% patients increased in the second data collection period from the first one. Images were taken from PET scanner in both records for 26 minutes though it has different percentage of contribution in total time. In 2nd observation CT study was completed within 8 minutes which is 4.5 minutes less than the 1st one. The device uses increased by 36% only due to reduced required time of computed tomography (CT). Hence the expense for this test of the patients will be reduced remarkably.

## 4. Discussion

The whole process of analysis for the PET/CT study and its individual steps led to the identification of critical points which allowed a better organization of the patient path and to a consequent increased number of examinations performed between the first and second data collection. It is important to highlight the fact that in literature the breakeven point for a PET/CT facility was estimated to be between 8 and 9 daily exams, a value confirmed by the management of the study center [13-14]. Therefore the number of performed procedures recorded during both data acquisition periods was below such breakeven point [15]. It is important to execute the maximum possible numbers of exams for the value of public health [16]. In PET/CT administration center, considering the patient pathway, the device's operational hours and the department's operative hours, calculated maximum number of exams that was performed two days in a week, Saturday and Tuesday, was 7 for 2nd data acquisition. The results of the first data acquisition recorded 5 daily performed exams. We also analyzed downtime and patient turnover time of the PET/CT scanner. This led us to a better management system (i.e. increased use of the machine), by reducing patient turnover time and consequently the device downtime. Between the first and second data collection, there was a 6.5% increase in the device usage rate while downtime reduced by 20 minutes for 2nd data period. Patient turnover mean time in the 1st data collection was 5 minutes, 2 minutes longer than in the 2nd data records. This decreased turnover time for 2nd data records showed that dead times were concentrated at the beginning and at the end of the day, and allowed the execution of an increased

number of exams in the second analyzed period, with an increase from 5 to 7 exams. In few cases architectural limitations are responsible for the patient's path time consumption; require longer times such as glucose test, the total length of the process decreased from 138 to 126.7 minutes. Second observation shows that 26% of the patients arrive, on average, 37 minutes early and that 59% of the patients underwent examination with an average delay of 25 minutes. Traffic is one of the unpredictable and uncorrectable factors which are responsible for the variability in patient arrival in the PET/CT centre. In order to reduce dead times, the patient, should start the exam execution process as soon as possible from its arrival. More punctual combination in every steps of PET/CT system and improved organizing capabilities will reduce dead times, which will be more beneficiary for the patients. Improved scheduling process and advance management system of the patient path is a mandatory in order to obtain greater punctuality in the PET/CT study execution and a more orderly flow with consequent benefits in terms of patient satisfaction. The half life of $^{18}$F-FDG is only 110 minutes. The examination is dependent on the decay life of $^{18}$F. So, excessive delay on patient's arrival may lead to limited availability of FDG- $^{18}$F (radioactivity). In PET/CT diagnostic investigation shows that, total required time for exam completion for the 2$^{nd}$ data acquisition is 5 minutes less than the 1$^{st}$ one.

We may reduce time, costs and stress by combining both PET and contrast-enhanced CT examinations at the same time in a single process. This consequently leads to increased schedulable CT time and shorter CT waiting lists.

Even with the architectural limitations some steps in the patient's path could not be reduced and sometimes, it required longer times such as glucose test. To obtain more efficient result, the PET/CT administration centre should give more preference to inform referring physicians and evaluate the clinical needs accurately of the patients before the examination.

## 5. Recommendation for PET/ CT

Variability in patient arrival was probably due to unpredictable and uncorrectable factors such as traffic. The patient should start the exam execution process as soon as possible from its arrival in order to reduce dead times. A further study could investigate whether punctuality in combination with a more prepared and smooth path could reduce dead times and offer more settlement for the patients. Therefore, more improvements in the scheduling process and in the management of the patient path have to be made taking on account of uncorrectable factors in order to obtain greater punctuality in the PET/CT study execution and a more orderly flow with consequent benefits in terms of patient satisfaction. Moreover, an excessive patient delay may lead to limited availability of $^{18}$F-FDG which is delivered considering the decay time of the radionuclide and the scheduled examination time. An additional point of concern to reduce time, cost and stress with the combination of the PET study and a diagnostic contrast CT examination.

## 6. Conclusion

The investigated result shows that, how comprehensively and accurately all examinations were performed and analyzed in PET/CT. Therefore, continuous activity control allow the identification of critical organizational and

structural issues; provide us useful information to the optimization in the use of expensive and sophisticated devices with a clear value in public health, great benefits for the patients and improved management results.

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