PET/CT versus CT in Patients with Non-Hodgkin's Lymphoma: A Students' Perspective

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Abstract

Non-Hodgkin's Lymphoma (NHL) is cancer of the lymphatic system and can be found where lymphocytes flow. The symptoms are diverse and there is no screening method available for NHL; therefore, identification of these symptoms aid in the diagnosis of this disease. Computed tomography (CT) is routinely used to diagnose NHL, however, it does not provide adequate results to properly diagnose all patients in all stages of lymphoma. [Flourine-18]Fluorodeoxyglucose ([F-18]FDG) positron emission tomography (PET) images fused with CT images provide enough physiologic and anatomical information for proper diagnosis. This research addresses the comparative findings between CT and PET/CT initial staging or restaging scans in patients with Non-Hodgkin's Lymphoma. Twenty patients were included in this research and underwent a PET/CT scan at University of Pittsburgh Medical Center (UPMC) Hillman Cancer Center and/or UPMC Magee Women's Hospital in Pittsburgh, Pennsylvania. These images were reviewed by the researchers in conjunction with a physician who is board certified in Radiology and Nuclear Medicine. Results proved that PET/CT is necessary for proper diagnosis due to undetected lesions or areas of metastases on the CT scan that were detected on the PET/CT scan.

Introduction

Non-Hodgkin's lymphoma (NHL) is cancer of the lymphatic system and is the twelfth most common cancer worldwide and fifth most common in the United States. It is associated with diverse symptoms such as enlarged lymph nodes, itching, infections, night sweats, lethargy, and anxiety. There is no screening method available for NHL; therefore, identification of these symptoms aid in the diagnosis of the disease (Wall, Glenn, & Poole, 2011).

Non-Hodgkin's lymphoma can be found in any part of the body where lymphocytes flow, these areas include: lymph nodes, liver, spleen, thymus gland, adenoids and tonsils, gastrointestinal mucosa, and bone marrow (Wall et al., 2011; Evans, Gilmore, & English, 2011). When comparing NHL and Hodgkin's disease (HD), NHL is more prevalent than HD. Determination between the two diseases depends on the presence of Reed-Sternberg cells, which are only found in HD. Reed-Sternberg cells are abnormal B-cells that are larger than normal white blood cells and can only be detected with a microscope (Evans et al., 2011).

NHL is categorized into slow progressing, fast progressing, and more aggressive types. Of the aggressive types, the most common are diffused large B-cell and follicular lymphomas, which account for more than half of the cases of lymphoma. In order to properly treat a patient diagnosed with NHL, accurate staging is imperative. There are two main types of staging techniques: Ann Arbor Classification and International Working Group response criteria. Ann Arbor classification is based on the extent of the involvement of the disease, symptoms, and bulkiness of the tumor. It is then classified from stages I through IV. International Working Group response criteria is a more invasive staging technique that utilizes biopsies and bone marrow evaluations accompanied with consideration of tumor size. Staging can be performed through several imaging modalities: magnetic resonance imaging (MRI), ultrasound (US), computed tomography (CT), positron emission tomography (PET), or PET/CT (Evans et al., 2011).

The primary choice for NHL initial staging is CT; it provides anatomical location, lesion size and shape, and detection of extranodal sites (Raanani et al., 2005; Fougere et al., 2006). However, it cannot be used exclusively for staging because early involvement is not always detectable, benign node enlargement reveals false positive results, and CT cannot distinguish between tumor and scar or necrotic tissue (Raanani et al., 2005; Seam, Juweid, & Cheson, 2007). Through the use of Hounsfield units, CT can only distinguish between tissue densities based on the numeric information contained in each pixel of the CT image. Although CT has a high sensitivity and specificity in initial staging, it does not provide as accurate results in the restaging of NHL (Seam et al., 2007). PET/CT is superior in the restaging process.

Positron emission tomography [F-18]FDG has a higher sensitivity and specificity, which provide metabolic and morphological information in NHL restaging (Fougere et al., 2006). PET/CT provides more information with limited increased radiation dose to the patient. PET/CT allows for shorter acquisition time because the patient can remain in the same position for both scans due to the fact that PET image acquisition is performed immediately after the CT scan. These two sets of images are fused for precise localization and accurate depiction of malignant or benign lymphoma tumors (Seam et al., 2007). PET alone does not provide accurate location of lesions, hence; PET/CT is the better staging technique and imaging modality than PET or CT alone (Raanani et al., 2005). This research will address the comparative findings between CT and PET/CT in patients with NHL, a students' perspective, because these imaging modalities alone may not always produce the same diagnosis.

Literature Review

In the article, *Value of PET/CT versus PET and CT performed as separate investigations in patients with Hodgkin's disease and non-Hodgkin's lymphoma,* la Fougèrè et al. studied the different values of positron emission tomography (PET)/computed tomography (CT) against separate PET and CT scanners for patients with non-Hodgkin's lymphoma (NHL) and Hodgkin's disease (HD). In this study a total of 100 patients with high-grade or intermediate HD or NHL participated in the study of [^{18}Flourine]fluorodeoxyglucose (FDG) PET/CT or as separate modalities in the initial staging or clinical re-treatment staging (r-staging). Fifty patients were scanned using a PET/CT scanner, while the other fifty patients were scanned separately on a PET and CT scanner within a time frame of ten days. The imaging method used is twelve bed positions with an acquisition of three minutes per bed for the PET/CT and PET acquisitions. The CT acquisitions for the PET/CT transmission data was a low-dose CT scan from the base of the skull to the proximal thighs with and automated intravenous injection of iodine-containing contrast. The separate CT scanner included images of the chest, neck, abdomen, and pelvis using spiral mode technique. The scan was performed after an automated intravenous injection of the iodine-containing contrast.

The results of the separately performed PET and CT scans concluded that in twenty-two patients, 111 lesions were detected by CT alone, and 113 lesions by PET alone. In a side-by-side comparison 122 lesions were interpreted. False positive results were returned in 36 lesions by CT and two lesions for PET. The results of PET/CT scan in twelve patients that participated in the initial staging were 57 lesions were detected by CT, 64 lesions in PET, and 65 lesions in PET/CT(la Fougèrè et al, 2006). Positron emission tomography/computed tomography found to be correct in all twelve patients.

In the article, *The role of FDG-PET scans in patients with lymphoma*, Seam et al studied how computed tomography (CT) scans were reliable enough for staging and restaging lymphoma, and how that has changed. Before positron emission tomography (PET) was used for the staging and restaging of lymphoma CT scans were used to determine the size and location of tumors. Unfortunately, a CT scan is unable to distinguish between viable tumors and scar tissue. PET/CT is a recent advanced modality for the assessment of lymphoma. Positron emission tomography shows high specificity and sensitivity in patients with Hodgkin's lymphoma and most subtypes of aggressive non-Hodgkin's lymphoma. Seam et al asked the question, should PET replace Ann Arbor staging for pretreatment evaluation? The answer may not be completely resolved, but PET is very valuable prior to therapy although it is not the current standard in pretreatment staging of lymphoma.

The role of PET is in restaging patients following therapy, which is performed as a final response assessment or determination of the extent of known or suspected recurrence of lymphoma (Seam, 2007). PET scans are more accurate than CT in distinguishing between necrosis or fibrosis in residual tumors. To predict the outcome during and after treatment, PET relies on dynamic properties of the tumor mass. PET has the potential to change the role of drug development.

In the article, *Is CT scan still necessary for staging in Hodgkin and non-Hodgkin lymphoma patients in the PET/CT era*, Raanani et al studied the impact that CT scans have had in the past and if they are still relevant since PET/CT scans have become more popular. To minimize morbidity related to the radio-chemotherapy staging is necessary. Staging is also necessary to prevent over or under treatment. Computed tomography (CT) is the principal staging tool for patients with lymphoma. CT is easily performed and readily available. There is

no evidence for therapeutic and diagnostic impact in a large series of patients. The purpose of this study is to evaluate the clinical effect of the PET/CT data on staging and the management of patients with Hodgkin and non-Hodgkin lymphoma. The study included 68 non-Hodgkin lymphoma (NHL) patients, they were biopsy-proven NHL that were in the study. These patients also had to have both a CT and PET/CT prior to receiving therapy. The PET/CT scan was acquired within twenty-four days of the diagnostic CT. Three data sheets were generated for analysis purposes. These data sheets included: clinical data sheet, diagnostic CT scan data sheet, and PET/CT scan data sheet. The clinical stage of the disease was established and proposed therapy was determined three times for the 68 NHL patients. The first decision was based on the CT scan alone, second decision was based on just the PET/CT scan, and third decision was based on both CT and PET/CT scans. There were differences found between staging on CT versus PET/CT. Conflicting staging was found in 22 patients by CT and PET/CT. The disease was upstaged in 31% of patients by PET/CT and down staged in one percent (Raanani et al., 2005). In CT versus PET/CT plus CT, the treatment suggested was different in 18 patients.

In the article, *The role of PET and PET/CT in managing the care of lymphoma patients,* Evans et al studied how PET and PET/CT differ in the scanning of lymphoma patients. Lymphoma is the fifth most common cancer in the United States. To determine whether or not the cancer is Hodgkin's disease (HD) or non-Hodgkin's lymphoma (NHL) is the presence of Reed-Sternberg cells. A Reed-Sternberg cell is an abnormal B-cell that is larger than a normal white blood cell (WBC) which is only found in HD through examination under a microscope. Lymphoma affects the lymph tissue in the body. These tissues can be found in lymph nodes, spleen, liver, adenoids and tonsils, thymus gland, digestive tract, and bone marrow. NHL can be divided into slow-growing, fast-growing, and more aggressive types (Evans, Gilmore, & English, 2011).

There are two systems used to stage the disease that Evans et al used: Ann Arbor Classification and International Working Group response criteria. Ann Arbor classification scales lymphoma I to IV through the extent of involvement of the lymphoma. Some symptoms that are common with lymphoma and bulkiness of the tumor can be incorporated into staging. The International Working Group response criterion is more invasive for the staging process to classify lymphoma through lymph node biopsy, and bone marrow evaluation. Evans et al compares PET/CT and diagnostic CT as well as the limitations of PET in this article. An advantage of PET/CT is that it can differentiate between actively malignant tissues and necrotic tissue. CT however, is unable to tell the difference. A limitation of PET is that [F-18] FDG is not just specific to cancer cell, it will show other sites where glucose metabolizes. Also, the radioactive sugar will be taken up where there is infection or inflammation. PET/CT is valuable for the management of lymphoma. This aids in staging and determination response to treatment.

In the article, *Experience prior to diagnosis of non-Hodgkin lymphoma: a phenomenological study*, Wall et al studies the emotions and experiences patients go through when being diagnosed with non-Hodgkin lymphoma (NHL). This study is to help identify and describe a patients experience during the period of time that leads to the diagnosis of NHL. Non-Hodgkin lymphoma is a cancer of the lymphatic system. This cancer can occur anywhere in the body that lymphocytes circulate. There is no screening process available so it is important to be aware of the symptoms. The people who participated in the study have been diagnosed with NHL and were willing to talk about their experiences leading up to the diagnosis. In depth interviews were used to collect data from the patients. Then, the patients were interviewed to

reflect back on the time when they first were aware of the health problem, and describe what it was like during the period of time leading up the their diagnosis. A reflective diary was given to each participant to write down their experiences before they were diagnosed with NHL. The findings overall theme was 'Creating a pathway towards hearing the diagnosis of NHL' (Wall, Glenn, & Poole, 2011). Another theme is advancing towards the focus on the NHL diagnosis.

The first theme describes the pathway of experience that ranges from initial symptoms to the point of diagnosis. In the theme of advancing towards the focus of the NHL diagnosis it was revealed to the participants at some point the diagnosis of NHL. This also consisted of two sub-themes: attending to initial perspectives that surround the diagnosis and bringing the diagnosis into focus. Coping with the reality of the diagnosis is different in every person. Some deal with reality through humor while others have a fighting spirit. Although these participants may not have enjoyed hearing what is wrong with them, they now can put a name on the symptoms and can move on to cope with their disease.

In the article, *Comparison of CT, PET, and PET/CT for staging of patients with indolent NHL,* Fueger et al investigates the potential impact of PET/CT compared to PET and CT on the staging of indolent non-Hodgkin lymphoma. Although PET has become the clinical standard for staging in patients with NHL, PET/CT is now being used more to stage lymphoma with higher accuracy than PET alone. This study uses 45 patients with indolent lymphoma that have under gone staging and restaging. PET/CT was performed on the Reveal RT scanner. It was combined with a dual-slice detector CT scanner. Patients received .21 mCi per kilogram of [F-18]FDG and also were asked to drink 900 milliliters of barium sulfate. Imaging began 45 minutes after tracer injection and the patients were positioned with arms up above the patients head. The CT acquisition was performed with intravenous contrast as well. Immediately following the CT acquisition the PET scan was started. Mid-thigh to the base of the skull was scanned and took from six to eight bed positions depending on the height of the patient.

The CT and PET images were interpreted independently by a radiologist and a nuclear medicine specialist. The PET/CT scans were read in harmony. The results showed that 33 of 45 patients had evidence of the active disease. A total of 117 of 585 nodal regions were found according to the reference standard (Fueger et al., 2009). PET/CT provides important information over PET and CT for staging and restaging of patients with indolent lymphoma. PET/CT is more likely to be a more beneficial in management of patients with indolent lymphoma rather than CT or PET alone.

In the article, *Comparison of CT, PET, and PET/CT for staging of patients with indolent NHL: Statistical Errors in Fueger et al. (2009),* White believes that Fueger et al has made some statistical errors in his research. Fueger et al has overstated the sensitivity, specificity, and accuracy of CT, PET, and PET/CT imaging modalities based on the data that was presented. The article has contributed excessive faith in PET/CT for restaging and staging of patients with indolent lymphoma. There have also been clinical trials which can determine the best protocols and treatments that rely on PET/CT scans. So far, there are no standards regarding PET or CT protocols either in practice or research.

In the Fueger et al article the definition of a positive PET/CT appears to leave no possibility for a lesion to be positive on PET/CT, but not PET-positive or CT-positive. When staging a patient with indolent NHL clinicians and researchers should not expect a high sensitivity from their PET/CT scans (Fueger et al, 2009). Over stated results may lead clinicians and researchers to have too much faith in the ability or their own PET/CT scans to identify sites of lymphoma.

In the article, *State-of-the-art research on lymphomas: role of molecular imaging for staging, prognostic evaluation and treatment response,* Kostakoglu and Cheson study the staging and evaluation of therapy response in lymphoma using molecular imaging modalities. Lymphomas are considered heterogeneous, but also potentially curable. PET/CT is used in staging and restaging for lymphoma, and shows convincing evidence that is a more accurate imaging modality compared to either imaging modality separately. CT relies on size and location, which means that it is unable to distinguish malignant from benign lymph nodes. PET is more accurate than CT at initial staging within the joint sensitivity and specificity of 96% (Kostakoglu & Cheson, 2013). Conflicting results between PET and contrast-enhanced CT occurs in approximately one-third of patients at initial staging. This is why most hospitals are in favor of PET/CT rather than PET and CT separately. Management of lymphoma requires both contrast-enhanced CT and low-dose PET/CT for morphological and metabolic assessment. Unfortunately, this increased the patient's radiation exposure. Studies are being performed to evaluate PET based metabolic tumor volume as a more accurate method to determine diseases.

In the article, *FDG-PET/CT in lymphoma*, D'souza et al believes that PET/CT is the cornerstone of staging of aggressive non-Hodgkin lymphoma (NHL). Lymphoma can arise from lymphomas. Understanding the role of PET/CT in the management of lymphoma and knowledge of its limitations is imperative for the utilization of this technique. A vital pre-requisite to therapeutic management is staging. CT is the most common imaging modality used for staging malignant lymphoma. It is used because of its availability and relatively low cost. The main advantage of PET over CT is the ability to detect metabolic changes in the areas that have the malignant lymphoma. PET can also detect more lesions than CT. An advantage of PET/CT is that it is a whole-body imaging method and it can guide the biopsy from the anatomical and metabolic activity. Lymph nodes are the most common sites that is affected by lymphoma. Lymph nodes are located in the following areas: cervical, supraclavicular, axillary, mediastinal, abdominal, and inguinal (D'sauza et al., 2013). Extranodal lymphoma is observed more frequently in NHL. In conclusion, PET/CT is now the foundation of staging aggressive NHL. It plays a very vital role in staging, restaging, prognostication, planning the correct treatment, monitoring therapy, and detection of recurring lymphoma. Further investigation is being performed because the role of PET/CT in indolent lymphoma is still unclear.

Materials and Methods

This research included 20 patients with NHL that were retrospectively reviewed by the researchers in conjunctions with the physician who is board certificated in Radiology and Nuclear Medicine. The scans were performed at the University of Pittsburgh Medical Center (UPMC) Hillman Cancer Center and/or UPMC Magee Women's Hospital located in Pittsburgh, Pennsylvania. Each patient had a [F-18]FDG PET/CT scan for either initial staging, or restaging after chemotherapy or radiation therapy.

Regarding patient preparations, all patients were to be nothing by mouth for four to six hours prior to the injection to maximize uptake. Their blood glucose levels were measured on an Abbott Labs glucometer and all were to be less than 200 mg/dL. Height and weight were obtained on all patients. Patients with prescription for oral contrast were administered 450 mL of Gastrografin®, a brand of oral contrast used for CT, mixed with water and lemonade flavored Crystal Lite prior to injection. All patients were aseptically injected with 12.0-20.0 mCi, plus or minus ten percent, of [F-18]FDG through a 20-22 gauge minimum intravenous (IV) catheter for proper IV contrast administration. Patients weighing over 91 kg were given more than 15 but

less than 20 mCi to accommodate their weight. After injection, the patients are taken to the uptake room, given a warm blanket, and asked to relax for 45 minutes to allow for uptake. After the first 20 minutes, all patients are administered another 450 mL of Gastrografin®. After the full 45 minutes, they are asked to empty their bladders before being positioned on the PET/CT scanner. A General Electric Discovery VCT PET/CT scanner was used for all imaging. A scout CT scan to assure maximum field of view was obtained. This was acquired before the full diagnostic or attenuation map CT scan. IV contrast was administered to prescribed pations for the full diagnostic CT scan. The full diagnostic CT scan was performed with the patients' arms up above their head, supine, and head first into the gantry. The CT scan is performed with a minimum of 40 and a maximum of 440 mAs, tailored to patient weight and a 120 kVp. A pitch of 0.984 and a speed of 39.37 mm per rotation were used in a helical CT scan. The PET portion of the scan was acquired immediately after the CT while the patient remained in the same position as for the CT. Approximately six to seven bed positions were acquired, depending on patient height, at four minutes per bed position.

The researchers visually assessed each CT image in Rad Assessment initially and areas with abnormal size, above 1.0 cm, or increased amount of lymph nodes throughout the body and abnormal Hounsfield values in the organs were noted. The physician would then confirm or correct the researchers' observations and explain in detail the patient's specific diagnosis. The same was carried out with the PET/CT image to compare observations with the CT image results. Any areas of increased uptake not identified on the CT image were noted for research statistics.

Results

This research included twenty patients, ages ranging from 43-81 years old (mean: 64 years old). Of the 20 patients, 13 of the patients were male and seven were female, half were undergoing initial staging, and the other half were undergoing restaging. The blood glucose level (BGL) for all the patients was required to be less than 200 mg/dl. For the patients in this study the BGL ranged from 81-175 mg/dl (mean: 105 mg/dl). Figure 1 and 2 shows all patient demographics in chart form categorized by initial and restaging scans.

Initial Staging Patient Demographics			
Patient	**Age**	**Gender**	**BGL (mg/dl)**
1	66	Male	90
2	35	Female	82
3	72	Male	104
4	64	Male	140
5	51	Male	88
6	43	Male	128
7	58	Male	86
8	80	Male	90
9	66	Male	81
10	69	Female	107

Figure 1: Patient Demographics for Initial Staging

Restaging Patient Demographics			
Patient	**Age**	**Gender**	**BGL (mg/dl)**
11	75	Male	102
12	71	Female	97
13	65	Male	119
14	81	Male	85
15	74	Female	98
16	55	Female	120
17	70	Female	106
18	54	Male	94
19	66	Male	175
20	48	Female	117

Figure 2: Patient Demographics for Restaging

Initial Staging Patients			
Patient	**CT Above Diaphragm**	**CT Below Diaphragm**	**PET/CT**
1	N/A	Lesion in liver	Increased uptake in liver
2	Enlarged and increase number of lymph nodes in the neck and mediastinum. Tumors in the pleural region	N/A	Increased uptake in bone marrow of vertebrae and esophagus.
3	Masses in right retroperitoneal region and displacing the liver and incasing kidney	N/A	Increased uptake in masses
4	Enlarged and increased number of lymph nodes beginning in the neck, extending into mediastinum and axillary, and around subcarinal, cardiophrenic regions	Enlarged and increased number of lymph nodes in the abdomen retroperitineum, and inguinal regions. Enlarged spleen.	Increased uptake in bone marrow of upper extremities, sternum, spine and pelvis. Increased uptake in spleen
5	Negative	Negative	Increase uptake in gastric wall of stomach
6	Enlarged and increased number of lymph nodes in the neck, subcarinal, and paraesophageal regions	Enlarged and increased number of lymph nodes in the abdomen. Ascites around liver/spleen. Liver lesion	Increased uptake in ascites. Decreased uptake of liver lesion (cyst).
7	Enlarged and increased number of lymph nodes in the neck and internal mammary glands. Bone metastases on sternum	Enlarged and increased number of lymph nodes in the abdomen. Bone metastases on spine.	Increased uptake in ribs and periportal lymph nodes. A second spot on sternum is detected.
8	N/A	Lumpy gastric wall	Increased uptake in gastric wall
9	Enlarged and increased number of lymph nodes in the neck, axillary, mediastinal, and cardiophrenic regions.	Enlarged and increased number of lymph nodes in the gastrohepatic, mesentery, inguinal, and periaortic regions. Massively enlarged spleen, and hypodense lesion in liver	Increased uptake in lesion on right posterior abdominal wall in muscle.
	N/A	Lesion in dome of liver	Increased uptake in liver

Figure 3: Initial Staging Patient Results

The research proved the PET/CT images confirmed suspicions on CT images, added diagnostic information to the CT images, were dependent on the patient's diagnosis, or were negative for lymphoma. Lymphoma was commonly seen in areas such as the mediastinum, axillary region, liver, and general abdominal region. Results from individual patients varied and are expressed in Figures 3 and 4.

Restaging Patients			
Patient	**CT Above Diaphragm**	**CT Below Diaphragm**	**PET/CT**
11	N/A	Lesion in liver	Increased uptake in liver
12	Enlarged and increased number of lymph nodes in left supraclavicular region.	Cysts in liver, lesions in spleen.	Increased uptake in axillary lymph nodes, malignant liver lesion.
13	Enlarged and increased number of lymph nodes in mediastinum.	Liver and adrenal lesions.	Increased uptake in neck and sub-pectoral muscle.
14	N/A	Enlarged and increased number of lymph nodes in mesentery	Increased uptake in mesentery lymph nodes.
15	Enlarged and increased number of lymph nodes in neck, mediastinum, and between the aorta and inferior vena cava.	N/A	Increased uptake in bone marrow of spine and internal mammary glands.
16	N/A	Dilated bowel and small bowel obstruction.	Increased uptake in bowel obstruction.
17	Negative	Negative	Negative
18	Negative	Negative	Negative
19	N/A	Hypodense lesion in liver.	Increased uptake in liver.
20	Negative	Negative	Negative

Figure 4: Restaging Patient Results

Discussion

The results of this research were divided into four categories. As mentioned previously, they are: the PET/CT images confirmed suspicions on the CT images, added diagnostic information to the CT images, were dependent on the patient's diagnosis, or were negative for lymphoma in initial staging and restaging scans.

In 40% of the patient data, the PET/CT images confirm the suspicions detected in the CT images. Half of the patients were undergoing initial staging and the other half were performed for restaging. For example, there were several CT images that presented with masses or liver lesions that may or may not have been malignant. The increased uptake demonstrated on the PET/CT images confirmed these findings were malignant. However, suspicions may not always be as obvious, for example, patient eight's CT image showed a lumpy gastric wall. Based on the patient's history, a reading physician could assume the gastric wall was positive for lymphoma, but as a students' perspective the CT would not suffice. In these cases, the CT images alone would have sufficed; however, the PET/CT images provide confirmation for correct diagnosis of lymphoma in these patients.

The majority of this research, 45%, proved PET/CT images added diagnostic information to the CT images. More than half of the patients, 66%, were undergoing initial staging scans for this category of research. Malignant bone marrow was the most commonly missed area of lymphoma in initial staging scans because CT has no way of detecting the difference, even with

the use of Hounsfield units. The CT images also did not detect other sites of malignant lymph nodes, which were prominent in two thirds of the restaging scans and the majority of initial staging scans. In addition to undetected malignant lymph nodes, the PET/CT images for patient 5 showed increased uptake in the gastric wall of the stomach, not seen on the CT images. There was, however, one restaging scan, patient 15, with increased activity in the bone marrow of the spine. Patient 15 proves PET/CT is necessary for accurate staging regardless if the patient is undergoing initial staging or restaging scans.

In association with the 45% of patients previously mentioned, 20% of the patient's diagnosis was dependent on the PET/CT images because the CT alone did not provide sufficient information. Bone marrow involvement changes the stage of lymphoma based on Ann Arbor Classification, therefore, patients would not have received proper treatment based on the CT images alone. As mentioned previously, patient 5 showed increased uptake in the gastric wall that was not seen on the CT scan. This patient's CT images were negative; therefore, if the PET/CT images were not obtained, the patient would have received false negative results for lymphoma and would not have been treated. The last 15% of patients' results, all restaging patients, were negative for both imaging modalities.

Conclusion

CT is the first choice in initial and restaging scans for NHL. However, PET/CT provides additional diagnostic information, can be diagnosis dependent, and ultimately alter patient treatment while only minimally increasing the radiation dose to the patient. PET/CT images are most useful in patients that are undergoing initial staging scans, but cannot be ruled out for restaging scans based on this research. Based on this research of a students' perspective, PET/CT is the most accurate and dependable imaging modality regardless of staging type when comparing CT images alone to fused PET/CT images in patients with Non-Hodgkin's Lymphoma.

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