Kufa Journal of Engineering
Vol. 6, No. 2, June, P.P.39-48
Received 15 September 2014, accepted 23 February 2015

STUDY OF MEDICAL IMAGING TECHNIQUES IN BREAST CANCER DETECTION

Ghasan Ali Hussain[1]

1 Asst. Lect., Department of Electrical Engineering, College of Engineering, University of Kufa, ghasan.alabaichy@gmail.com

ABSTRACT

Medical imaging is a process and technique used to create images to the human body or parts and function thereof for clinical purposes, to medical procedures seeking to reveal, diagnose or examine disease or medical science. In this paper we will explain three types of medical imaging techniques; Magnetic resonant Imaging (MRI), Positron Emission Tomography (PET) and Ultrasound (US) that are used in the breast cancer detection, then we will compare among them to know which one of this techniques are better to use in the detection of breast cancer by taking in the account all of the sensitivity, resolution, cost and side effect. The results show that superior of MRI against the both of PET and Ultrasound in the sensitivity and resolution, while the disadvantages of MRI techniques was the high cost and time required to get imaging.

KEYWORDS

Breast cancer, Medical Imaging, MRI, Ultrasound, PET.

دراسة تقنيات التصوير الطبية في فحص سرطان الثدي

المدرس المساعد غسان علي حسين

قسم الهندسة الكهربائية – كلية الهندسة- جامعة الكوفة

الخلاصة

التصوير الطبي هو اجراء و تقنية تستخدم لإنشاء صورة لجسم الانسان او جزأ من جسمه لأغراض التشخيص السريرية و للإجراءات التي تتطلب فحص، و لتشخيص او اختبار مرض او لأي غرض طبي آخر. في هذا البحث سنوضح ثلاثة أنواع من تقنيات التصوير الطبي المستخدمة في الكشف عن هذا المرض و هي تقنيات الرنين المغناطيسي و تقنيات التصوير الاشعاعي و تقنيات الموجات الفوق السمعية. ثم سنقوم بإجراء مقارنة بين هذه التقنيات الثلاثة لتوضيح أي التقنيات هي الأفضل في الكشف عن مرض سرطان الثدي بعد الأخذ في الاعتبار كل من الحساسية و دقة الوضوح و التكلفة اضافة الى الآثار الجانبية المترتبة عن استخدام هذا الجهاز لجسم الانسان. أثبتت نتائج المقارنة أن هناك أفضلية لتقنيات الرنين المغناطيسي على تقنيتي الاشعاع و الموجات فوق السمعية من ناحية الحساسية و الدقة بينما ما يعيب على تقنيات الرنين المغناطيسي هو التكلفة الباهظة و المدة الزمنية الطويلة للحصول على الصورة.

الكلمات الدلالية

سرطان الثدي، التصوير الطبي، التصوير بالرنين المغناطيسي، أشعة فوق السمعية، تقنية التصوير الشعاعي.

1. INTRODUCTION

Breast cancer is the most common cancer among women worldwide. Several investigations have reported the association of higher tumour recurrence rates with positive or close margins than with negative margins after breast-conserving therapy (BCS). Therefore the accurate evaluation of the extent of cancer, including components of intraductal around the main tumour, is an very important factor to limiting the tumour recurrence [1]. Earlier there is retrospective study for Sundararajan [2], it conducted a comparative investigation of the roles of ultrasound and magnetic resonance imaging in detecting the extent of intraductal components.

The results showed that sensitivity of US in detecting wide intraductal components was higher than that of MRI but no significant differences were proven statistically. Moreover, in this earlier study, the direction of intraductal components was not discussed because in the retrospective study, some of the records did not note the direction.

2. MEDICAL IMAGING TECHNIQUES

The excellent soft tissue contrast and spatial resolution, coupled with tomographic imaging which avoids tissue overlap and the absence of radiation, makes magnetic resonance imaging an appealing imaging modality. Traditionally, mammography has been the mainstay of diagnosis and staging of breast cancer, but even in the best circumstances its sensitivity lies between 69 and 90% [3]. Ultrasound (US) is a good technique for assessing palpable abnormalities, distinguishing cystic from solid lesions, classifying solid masses and facilitates accurate needle placement for biopsy. It is limited, however, in the identification of ductal carcinoma in situ (DCIS) and it is also difficult to ensure that the entire breast has been imaged [4]. Several researchers are shown that MRI have a higher accuracy in delineating breast cancer when compared with histopathological findings than both ultrasound and mammography [5, 6].

In the past two decades, enormous advances have been made in the field of (MRI) of the breast cancer detection. The Investigators have been focused on this technique, interpretation criteria and clinical indications for MRI in many clinical trials.

Recently, the International Working groups on breast MRI, including the characterization working group, the staging working group, the high-risk screening group, the biopsy and intervention group and the consumer affairs working group were introduced to clarify issues like ‘‘when should MR imaging be used?’’, ‘‘Is there a standard or optimal technique, are there standard interpretation criteria and standard indications?’’, ‘‘Should MRI be used for cancer screening?’’, Which patients would benefit most from MR imaging?’’, ’’Are breast cancers detected with MRI only of clinically importance?’’ and ‘‘Is the imaging test cost-effective?’’ These different working groups not only have summarized the results of previous studies on specific topics, they also presented and encouraged the incorporation of breast MR in new trials [7].

Clinicians, radiologists and surgeons are increasingly interested in the true value of breast MR as a standard imaging technique in daily clinical practice [8].

Different radiopharmaceuticals have been investigated to improve diagnosis of breast cancer. Fluorine-18 labeled 2-fluoro-2-deoxyglucose (FDG) and positron emission tomography has provided additional information in breast cancer patients when mammography was indeterminate. However, the fact that small tumors under 1 centimetre in diameter are often missed, the high costs and limited availability will confine the use of FDG-PET in detecting primary breast cancer to selected centres. FDG-PET can also be used to stage breast cancer patients for lymph node and distant metastases. As for primary breast cancer, it has been shown that lymph node metastases below a size of 8–10 mm are detected with a lower sensitivity [9].

The members of European Group for Breast Cancer Screening are considered that uses ultrasound in the breast diagnosis and breast cancer screening. After wide consultation and a detailed literature review, the consensus of the Group on the role of ultrasound is as follows: the current evidence indicates that ultrasound of the breast is an important to adjunct the mammography and clinical examination in the further assessment of both palpable and impalpable breast abnormalities. However, the use of ultrasound in population screening of asymptomatic women is associated with unacceptably high rates of both false positive and false negative outcomes. At present there is little evidence to support the use of ultrasound in population breast cancer screening at any age [10].

3. METHODOLOGY

Here will discuss the methodology and explain the concept each of among three types of imaging techniques (MRI, Ultrasound and PET):-

3.1. Magnetic Resonance Imaging (MRI)

Magnetic resonance imaging (MRI), or nuclear magnetic resonance imaging (NMRI), is primarily a medical imaging technique most commonly used in radiology to visualize detailed internal structure and limited function of the body [11].

Compared to a CT scanner which uses X-rays, a type of ionizing radiation to acquire its images, MRI uses non-ionizing radio frequency signals to acquire its images. It is a non-invasive method used to render images of the inside of an object. Unlike CT, which uses only X-ray attenuation to generate image contrast, MRI has a long list of properties that can be used to generate image contrast. By variation of scanning parameters, tissue contrast can be altered and enhanced in various ways to detect different features. MRI can generate cross sectional images in any plane (including oblique planes) as in Fig. 1.

The human body consists of water molecules, and each of them consists of both hydrogen nuclei or protons. When the patient goes inside of the MRI machine which has powerful magnetic field of the scanner, the magnetic moments of these protons align with the direction of the field. Then the radio frequency is briefly turned on, causing the protons to alter their alignment relative to the field. When this field is turned off the protons return to the original magnetization alignment, these alignment changes create a signal that can be detected by the scanner. The frequency at which the protons resonate depends on the strength of the magnetic field. The position of protons in the body can be determined by applying additional magnetic fields during the scan which allows an image of the body to be built up. These are created by turning gradients coils on and off which creates the knocking sounds heard during an MR scan [12].

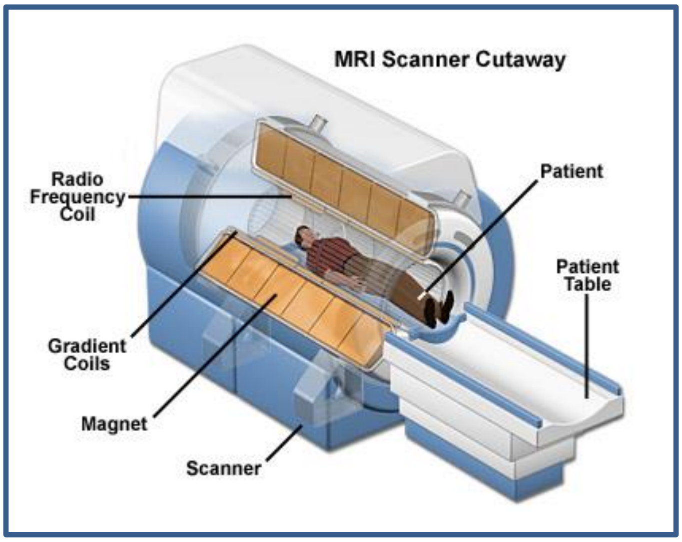

Fig. 1. MRI Scanner Cutaway [13]

In other words, the study object is placed within a high intensity magnetic field. This causes the magnetic moments of the molecules within the object to become aligned. then the object is irradiated with pulses of low-level microwave radiation (excitation pulses) that will cause a magnetic moments of the molecules to oscillate and re-emit microwaves after each pulse. All these re-emissions are measured and stored digitally. By introducing gradients in the background magnetic field, it is possible to determine the spatial location of a re-emitted microwave. This image representing various characteristics about the molecular emissions at discrete samples throughout the object scanned is then formed. By modifying the frequency and timing the characteristics of the excitation pulse, and the delay time before measurement of the emitted energy, it is possible to image particular types of molecules (water for instance), movement (blood flow), and many other characteristics as shown in Fig. 2 [14].

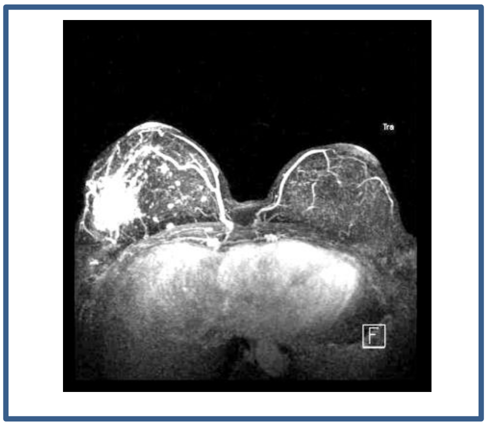

Fig. 2. Image Characteristics

The examinations of MRI breast are performed with the patient prone in a 1.5 Tesla magnet (Symphony, Siemens Medical Systems, Iselin, NJ) by using a dedicated surface coil. The imaging protocol includes a localizing sequence followed by axial T2; an axial 3D T1 weighted gradient echo sequence is then performed before and three times after a rapid bolus injection of gadolinium. After this examination, the un-enhanced images are subtracted from the first contrast-enhanced images on a pixel-by-pixel basis. These MRI scans can only be done prone because of the importance of the enhancements offered by the coil, as tissue contrast is a combination of contrast material and coil. Motion artefacts are a problem. Thus, most MRI coils have a strut that holds the breast in the place without purposely compressing it. The patients with large breasts may have some compression because the size limitations inherent in the coil (CP breast array, Siemens Medical Systems, Iselin, NJ). Also, mis-positioning, illustrated in Fig. 3, is a problem for registration [15].

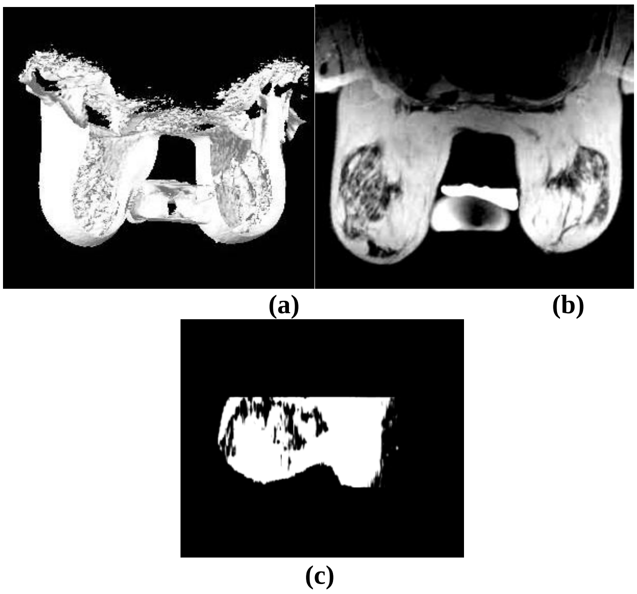

Fig. 3. (A) A 3D view of the pendant breasts. (B) Axial projection and (C) sagittal projection. In (A) and (B), the slight mis-positioning in the MRI coil of the breast shown on the left side is apparent.

3.2. Positron Emission Tomography (PET):-

Positron emission tomography (PET) as in Fig. 4, is a non-invasive imaging method that exploits the decay physics of positron-emitting isotopes such as isotopes of oxygen, carbon, nitrogen and fluorine [16, 17].

Fig. 4. PET machine

PET is a type of nuclear medicine procedure that measures metabolic activity of the cells of body tissues. PET is a combination of nuclear medicine and biochemical analysis. It is mostly used in patients with brain or heart conditions and cancer, it can be helps to visualize the biochemical changes taking place in the body, such as the metabolism (the process for which cells change food into energy after food is digested and absorbed into the blood) of the heart muscle. The difference between examinations of PET and other nuclear medicine examinations is that PET detects metabolism within body tissues, whereas the other types to detect the amount of a radioactive substance collected in the body tissue in a certain location to examine the tissue's function [18].

In PET, they inject the patient of a metabolically active tracer-a biological molecule which carries with it a positron-emitting isotope (like 11C, 13N, l5O, or 18F). through a few of minutes, the isotope will accumulates in the area of body that the molecule has an affinity. For instance, the glucose labeled with 11C (half-life, 20 min), or a glucose analogue labeled with 18F (half-life, 1.8 hr.), it will accumulates in the brain, where glucose are used as the primary source of the energy. The radioactive nuclei then decay by positron emission. The emitted positron collides with a free electron usually within less than 1 mm from the point of emission. The interaction of the two subatomic particles results in a conversion of matter to energy in the form of two gamma rays. These high-energy gamma rays emerge from the collision point in opposite directions, and are detected by an array of detectors which surround the patient [19].

PET is not currently indicated to use for breast cancer detection. Several studies show there are a lot of limitations, the main limitation is a poor spatial resolution of PET. The sensitivity of PET is good but there is problem if used to detect breast lesion under 1 cm because it has remains low around 57%, also PET cannot be used for screening. However, other studies have been suggested that the incidental lesions or lesion seen in symptomatic patients must be considered as malignant until to prove otherwise [20].

3.3. C. Ultrasound:-

Ultrasonic imaging utilizes acoustic energy to form an image of the body. A beam of high frequency (3-10 Megahertz) acoustic energy is directed into the body. Acoustic energy that is reflected from body tissues is detected by an acoustic transducer (typically located near the source) and transformed into an image. Typically, the sound source and transducer are mounted together on the hand held probe. The Sonographer, places the probe against the body, and moves it to obtain images of various parts of the body. Most ultrasound machines consist of a linear array of transducers, and produce an image representing a pie- shaped slice of the body as in Fig. 5. One of the prime advantages of an ultrasonic imager is that it produces images in real time [21].

This medical technology's non-radioactive nature has made it the modality of choice for ob-gyn procedures. In fact, it is most commonly associated with foetal imaging Fig. 6. Advances in ultrasound technology have resulted in applications that extend far beyond foetal imaging to include cardiac, vascular and breast imaging, as well as cyst identification and guidance of a variety of surgical and other therapeutic procedures. Ultrasound is also used for other applications such as measurement of blood flow in the blood vessels, etc.

Fig. 5. Ultrasound Machine

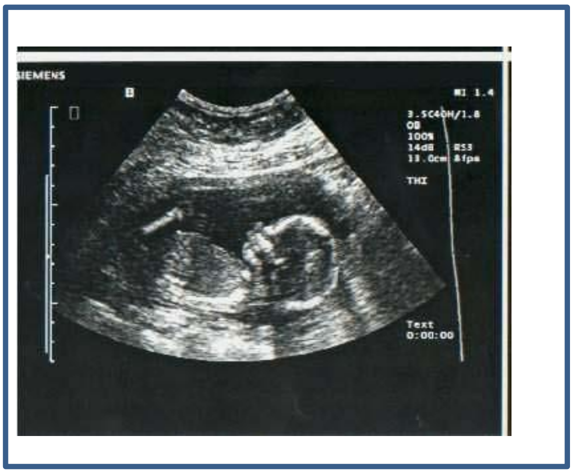

Fig. 6. Foetus ultrasound[21]

The accuracy rate in the diagnosis of simple benign cysts of breast ultrasound (BUS) images can be increased, and the lesions characterized as benign cysts do not require biopsies. It has been shown that sonography is superior to mammography in two aspects: the first, its ability to detect focal abnormalities in the dense breasts of adolescent women; and second, the fact that ultrasound images are acquired with a relatively lower health risk to the patient, and at a lower cost [22].
Ultrasound also can to detects the moving structures (blood flow) by using Doppler Ultrasonography, to assess heart functionality, identify abnormalities in blood flow and assess vascularisation of lesions (cancer).

4. RESULT AND DISCUSSION

After explaining all of the three types of medical imaging and related them with the breast cancer detection, also explained how they works and image acquired to them from [1-23], now we will discuss and doing the comparison between them as following:-

Table 1.

Comparison for three of medical Imaging in breast cancer detection [1-23]

Imaging Techniques	MRI	Ultrasound	PET
Sensitivity	High, can detect very small size tumors	good	High, but Low under 1 cm around 57%
Cost	Expensive	Cheap	Expensive
Speed	Slow (40 -90 min)	Quick	Slow (0.45 -1 h)
Resolution	High detailed pictures, and can get 3D image	poor quality	Poor quality
Side Effect	harmless	harmless	Little ,But not recommended for a person has already diseases
Notes	can detect a leak or rupture in a breast implant	Many cancers are not visible Cannot determine if a mass is cancerous, and a biopsy may be recommended	It has good sensitivity in the other diseases

The above comparison of medical imaging techniques shows that the MRI is the best choice for breast cancer detection by compared with the Ultrasound and PET, that is because it has high sensitivity of MRI to the breast cancer, also it can to detect very small size of tumors, but in the same time this technique is very expensive and very slow to get the imaging by compare it with Ultrasound.
PET scan can to detect the cancers in their earliest stages. Since a PET scan images the metabolic activity of the body’s tissues, even it can often show the tumors pathology before anatomical or structural changes are evident on conventional imaging. While, when an x-ray,

MRI or CT shows a lesion, it may not accurately characterize whether it is benign or malignant. PET can often make this determination, thereby sometimes it avoiding surgical biopsy when the PET scan is negative (which would be indicate that the lesion is benign). But, in certain cases when a PET scan is indicates a positive for cancer that has already spread (metastasized) to other organs, and if the surgical cure is not possible thereby the chemotherapy may be recommended. PET allows for far greater accuracy in the diagnosis and staging of many kinds of cancer. In cancers where surgery is the best step of action, the PET/CT fusion scanners provide the surgeons with the ability to not only differentiate between the benign and malignant tumors, but it also shows them exactly where the tumors are be located, thereby allowing for more targeted and often shorter surgeries, which may decrease patient morbidity [23].

Although this benefits of PET and it has a high sensitivity may can to superior the MRI in tracer study and its chemical specificity, this candidate the PET to use in the brain and other body tissues. But inability to detect the very small tumors in the breast made it rare use in the public imaging for breast cancer detection.

5. CONCLUSION

In this paper, we studied three types of medical imaging techniques used in breast cancer detection; Magnetic Resonance Imaging (MRI) against both of Ultrasound and Positron Emission Tomography (PET) imaging, also we explained the specifications of the machine and how the image is acquired, then the comparison among of them has been done, the results show that superior of MRI against the both of PET and Ultrasound in the sensitivity, while the disadvantages of MRI techniques was the high cost and time required to get imaging.

REFERENCES

[1] S. Sundararajan, E. Tohno, H. Kamma, E. Ueno and M. Minami, “Role of ultrasonography and MRI in the detection of wide intraductal component of invasive breast cancer a prospective study,” Clin Radiol., vol. 62(3), pp. 252-261, Mar. 2007.

[2] S. Sundararajan, E. Tohno, and E. Ueno, “Detection of intraductal component of invasive breast cancer by US: comparison with MRI and histopathology,” *Radiat Med.*, vol. 24(2), pp.108-114, Sep. 2006.

[3] Kacl GM, Liu P, Debatin JF, Garzoli E, Caduff RF, and Krestin GP, “Detection of breast cancer with conventional mammography and contrast enhanced MR imaging,” *Eur Radiol.*, vol. 8, pp. 194–200, 1998.

[4] Jackson VP, “The current role of ultrasonography in breast imaging,” *Radiol Clin North Am.*, vol. 33(6), pp. 1161-1170, Nov. 1995.

[5] PL Davis, MJ Staiger, KB Harris, MA Ganott, J. Klementavicenne, and KS McCarty, “Breast cancer managements with magnetic resonance imaging, ultrasonography, and mammography,” *Breast Cancer Res Treat*., vol. 37, pp. 1–9, 1996.

[6] L. Esserman, N. Hylto, L. Yassa, J. Barclay, S. Frankel, and E. Sickles, “Utility of magnetic resonance imaging in the management of breast cancer: evidence for improved preoperative staging,” J Clin Oncol., vol. 17(10, pp. 110-119, Jan.1999.

[7] S. Harms, C. Lehman, S. Klimberg, and R. Garcia, “Introduction to the international working groups on breast MRI,” *Breast J*., vol. 10, pp. 1-2, Oct. 2004.

[8] M. Van Goethem, W. Tjalma, K. Schelfout, I. Verslegers, I. Biltjes, and P. Parizel, "Review Magnetic resonance imaging in breast cancer", *The Journal of Surgery*, vol. 32, pp. 901-910, 2006.

[9] H. Palmedo, J. Hensel, M. Reinhardt, D. Von Mallek, A. Matthies, and HJ. Biersack, "Breast cancer imaging with PET and SPECT agents: an in vivo comparison," Nucl Med Biol., vol. 29 (8), pp.809-815, Nov. 2002.

[10] W. Teh and A.R.M. Wilson, "The Role of Ultrasound in Breast Cancer Screening. A Consensus Statement by the European Group for Breast Cancer Screening," *European Journal of Cancer*, Vol. 34(4), pp. 449-450, Mar. 1998.

[11] Magnetic resonance imaging, Wikipedia, 26 June 2014, http://en.wikipedia.org/wiki/Magnetic_resonance_imaging

[12] How MRI Works, October 10, 2009 http://voltazman.blogspot.com/2009/10/how-mri-works.html

[13] Magnetic Resonance Imaging, March 02, 1999, G. Scott Owen, http://www.siggraph.org/education/materials/HyperVis/applicat/medical/mri.htm

[14] Noz, M.E. Moy, L. Ponzo, F. Kramer, E.L. Maguire, G.Q., and Jr., "Can the specificity of MRI breast imaging be improved by fusing 3D MRI volume data sets with DG PET?," *IEEE*, vol. 2, pp. 1388-1391, Apr. 2004.

[15] EM Rohren, TG Turkington, and RE Coleman. "Clinical applications of PET in oncology," *Radiology*, vol. 231(2), pp. 305–332, Mar. 2004.

[16] TM Blodgett, and CM Meltzer, "Townsend DW. PET/CT: form and function," *Radiology*, vol. 242, pp. 360–385, Feb. 2007.

[17] Malik E. Juweid, M.D., and Bruce D. Cheson, M.D," Positron-Emission Tomography and Assessment of Cancer Therapy", The new England journal of medicine, pp. 496-507, february 2, 2006

[18] Positron Emission Tomography (PET), June 17, 2003, http://bioeng.berkeley.edu/budinger/pet.html

[19] R. Lavayssière, AE Cabée, and JE Filmont, "Positron Emission Tomography (PET) and breast cancer in clinical practice," *European Journal of Radiology*, vol. 69(1), pp. 50-58, Jan. 2009.

[20] Vincent Gregoire, Arturo Chiti., "PET in radiotherapy planning: Particularly exquisite test or pending and experimental tool?", Published by Elsevier Ireland Ltd., Radiotherapy and Oncology 96 (2010) 275–276

[21] Ultrasound, March 02, 1999, G. Scott Owen, http://www.siggraph.org/education/materials/HyperVis/applicat/medical/ultra.htm.

[22] Xiangjun Shi, H.D. Cheng, Liming Hua, Wen Jua, Jiawei Tian, "Detection and classification of masses in breast ultrasound images," *Academic Press, Inc. Orlando, FL USA*, vol. 20(3), pp. 824-836, Mar. 2009.

[23] Clinical Applications of PET & PET/CT, 2009, Metro Region PET Center, LLC. http://www.petimagingflorida.com/hp/clinical_apps.html