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Imaging Techniques for Detecting Breast Cancer: Survey and Perspectives

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Abstract

Breast cancer is the most commonly diagnosed cancer and the second leading cause of cancer death among women in America. A few years ago, the odds of developing breast cancer were reported as 1 in 13. Now the chance is 1 in 9. The only way today to find out for sure if a breast lump or abnormal tissue is cancer, is by having a biopsy: A suspicious tissue is removed by a surgical excision or needle biopsy and is examined under a microscope by a pathologist who makes the diagnosis. Imaging techniques of the breast are therefore vital since they will allow early detection of cancer, and localization of the suspicious lesion in the breast for a biopsy procedure.

Comments

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Introduction

Breast cancer is the most commonly diagnosed cancer and the second leading cause of cancer death among women in America. A few years ago, the odds of developing breast cancer were reported as 1 in 13. Now the chance is 1 in 9. The only way today to find out for sure if a breast lump or abnormal tissue is cancer, is by having a biopsy: A suspicious tissue is removed by a surgical excision or needle biopsy and is examined under a microscope by a pathologist who makes the diagnosis. Imaging techniques of the breast are therefore vital since they will allow early detection of cancer, and localization of the suspicious lesion in the breast for a biopsy procedure.

1) The present-day detection methods

The established technique for breast imaging, both screening and diagnostic, is film-screen mammography. Using film-screen mammography it is possible to detect about 85% of breast cancers and find these at an early enough stage to reduce mortality by approximately 50%. Mammography is the most commonly used imaging technique today throughout the world. When a patient undergoes a mammography a beam of X-rays traverses the breast and creates a projected image on a film.

2) Weaknesses of present-day methods, and what has created the need for new methods:

- Ability to read mammograms varies enormously among Radiologists
- Mammography has a low specificity. The likelihood that a lesion found by mammography and sent to biopsy will be malignant is only 20 to 35%.
- Densities of tissues are similar and the lack of contrast often masks tumors. Problem with dense breasts, leads to decreased sensitivity
- X-ray radiations are known to cause damage to DNA of cells.

3) New methods

A) MRI Imaging

a) Breast cancer diagnosis with High Field MRI (1.5T)

Magnetic resonance imaging uses radio waves and magnetic fields to diagnose diseases. Patients are asked to lie on a table during the test, which takes about 30 minutes. They are then advanced into the MRI machine, which contains a very strong magnetic field. The method consists of injecting a contrastenhancing dye-like material into the patient's bloodstream and using magnetic resonance imaging to monitor the way in which this material is taken up and cleared out by the tumor tissue.

The ability to identify a mass in the breast requires that the mass has a different appearance (or a different contrast) from normal tissue. With MRI, the contrast between soft tissues in the breast is 10 to 100 times greater than that obtained with x-rays (several studies have indicated that MRI can detect cancers that are not seen on mammography). The main disadvantage of breast MRI is its cost, which is about 5 times that of X-ray mammography.

b) MR guided biopsy with open systems (mid-field)

Open configuration MR imaging systems consists of a low-field (0.5T) superconducting magnet of an open configuration that allows access to the interventional field. The system was built with the major goal of guiding therapies: imaging may be performed during the procedure, in nearly real-time. This means that the radiologist can select the image plane during the procedure, before and during needle advancement. Those systems are still in the experimental stage, are very expensive, and very few are actually in use throughout the world.

B) Digital Imaging

In digital imaging, the digital image is formed when a detector absorbs the x-rays and converts them to an electrical signal corresponding to each pixel. When images are digitally acquired and displayed, film is eliminated. This eliminates the expense, time and effort, for film processing.

a) Stereotactic imaging

Stereotactic breast biopsy procedures are the only currently commercially available digital mammography technology. Stereotactic biopsy systems use small-field digital detectors, and offer radiologists the ability to target a lesion discovered during mammography, to accurately place a needle into its center, and to remove tissue samplings. With Stereotactic biopsy, the patient has an opportunity for a less costly, less invasive, and more cosmetically acceptable procedure that she has with excisional biopsy.

b) Full field digital mammography

Still experimental. When available, these will be considerably more expensive than film-screen imaging systems. The National Cancer Institute predicted that digital mammography is "the evolving technology with the greatest potential impact on management of breast cancer". The challenge for FFDM is to provide high-resolution, high-contrast images with the lowest possible radiation dose to the patient.

c) Single Energy X-ray technique

This new method is called defraction-enhanced imaging (DEI). It creates significantly sharper, more detailed pictures of breast tissue, which could dramatically improve the efficacy of mammography. The new imaging method uses a single-energy X-ray source. This method is still experimental, and a lot of work need to be done before it can be used with patients.

d) 3D digital reconstruction

This 3D technique is an adaptation of a digital technology used in hospitals all over the world to guide needle biopsies to diagnose breast cancer. Stereotactic breast biopsy tables with digital detectors are commonly used to image the breast and guide the probes that obtain tissue samples. The image quality of these systems is very good, and the adapted systems can create three-dimensional or two-dimensional images of the breast. This technique can improve the accuracy of mammographic diagnoses.

e) Tomosynthesis

In the tomosynthesis method, multiple images are acquired as the x-ray tube is moved in an arc above the stationary breast and digital detector. the total radiation dose required for imaging the entire breast being approximately equal to the dose used for a single film-screen mammogram. By shifting and adding the images, it is possible to bring any plane of the breast into sharp focus. Tomosynthesis has the potential to improve the specificity of mammography by reducing the contribution of normal fibroglandular breast to mask the presence of a lesion. The potential benefit will be largest in women with radiographically dense breasts

f) Computer-aided diagnosis

Digital mammography also offers advantages that are possible with linkage to computer aided diagnosis (CAD) systems, because the digital information is available in a format that is usable by CAD systems. CAD may be possible with FFDM serving almost as a "second reader". The computer may automatically draw a border around areas of abnormal contrast, calling the radiologist's attention to suspicious regions. Other software techniques use pattern recognition and small object detection to detect microcalcifications in digitized mammograms.

C) Ultrasound Imaging

a) High frequency Sonography

Sonography has the ability to demonstrate margins and internal texture, often more fully than mammography. Most importantly, this makes it possible to diagnose simple cysts within the breast. In many patients sonography also makes it possible to increase or decrease suspicion that a lesion is malignant and to more accurately map the extent of tumor within the breast than is possible with mammography.

b) Vascular imaging: Doppler, power Doppler, color Doppler

Carcinomas of the breast show remarkable changes of vascularity, which are essential for their enhanced metabolism. Doppler imaging allows investigating normal and pathological vascularisation in the breast. The technique is non-invasive, fast and easy. color is used to encode blood velocity or volume.

c) Contrast Imaging

Ultrasound contrast imaging is a recent technique in which a "contrast agent" consisting in gas microbubbles is injected intravenously. The microbubbles act as echo-enhancers which cause the received signal to be longer and greater in the cancers than in the benign lesions. The cancers also display characteristic vascular morphologic features, with more additional vessels visualized in relation to the lesion. Contrast imaging can be effectively used with vascular imaging. The signal-to-noise ratio is markedly improved, and diagnostic confidence is increased. Ultrasound imaging using microbubble contrast agents will definitely open up new opportunities.

d) Sonoelasticity

It is the use of ultrasonography to visualize in real time the hardness or stiffness of tissues and organs by depicting the tissue's motion in response to an applied vibration source. As a result, hard or dense tumors that are undetectable by conventional ultrasonography often can be visualized in sonoelasticity imaging by virtue of their altered vibration response.

e) Guided biopsy

Using real-time imaging like a motion picture, the ultrasound-guided system allows for definitive diagnosis of breast tissue. This technique can be used along with mammography.

D) Nuclear Imaging

a) PET Imaging

With PET, patients are injected with a glucose that has been labeled with a radioactive tracer. Cells that are undergoing more metabolic activity, such as sites of infection and cancer, will take up more glucose. Positron radioactivity emitted by the radiolabeled glucose is recorded by a PET camera, processed and reconstructed by computer so that the areas of greatest metabolic activity light up on a computer-generated image, which is much like a conventional CT scan. Due to its high cost and the limited availability of the traced isotope, widespread use of PET scanning is unlikely. PET imaging also allows doctors to predict within about a week of starting hormone therapy if women will likely respond (doctors would normally wait several months for signs of tumor shrinkage). In some countries a PET scan is required to determine whether a cancer has spread before a patient undergoes surgery.

b) Sestamibi imaging

The most frequently reported tracer applied to breast imaging has been Tc-99m-sestamibi. They are radioactive isotopes, often attached to biologically active molecules, and are usually injected into patients. These radiopharmaceuticals are designed to target the specific part of the body to by studied. A gamma camera is used to transform the radiopharmaceutical emissions into useful diagnostic images that illustrate both function and anatomy. Sestamibi scanning of the breast has only been shown to be effective in relatively large breast cancers, and its role in the diagnostic armamentarium of breast imagers remains unestablished.

E) BioElectric Imaging

This breast imaging technique is designed to assist in the detection of early stage tumors and pre-cancerous lesions without X-rays or discomfort to the patient.. Changes in cellular water content and cell membrane properties cause a significant change in tissue electrical impedance, enabling cancerous and pre-cancerous lesions to be visualized in the image. Procedures resemble an ultra-sound with no physical discomfort nor radiation. The system should be particularly effective in detecting breast tumors in younger women (under the age of 50) who have denser breast tissue which cannot be readily examined wit traditional mammography.

F) Optical Diffusion Imaging

Imaging with light in the Near Infrared (NIR) has gained increasing interest the last few years due to the very attractive potential of probing tissue oxygenation and metabolism, non-invasively, employing relatively low cost instrumentation and using non-ionizing radiation. Tissue has a low absorbing window in the NIR that allows light penetration of several centimeters employing laser power. The information obtained depends on the attenuation characteristics of breast tissues at visible and near-infrared wavelengths and can be used to determine tissue malignancy.

3) How well are the new methods used throughout the world?

Digital mammography is used primarily in the U.S. and Canada (but is also used in Europe). Bioelectric imaging is used mostly in Europe. PET imaging is widely accepted in Europe, but has had limited use in the US. MR imaging is used in the U.S. and in Europe.

4) Future projects in imaging in this country and in other countries: frontiers in breast imaging

A) High risk screening: Economy is a big driving force

Create a relative risk number for women based on the most significant risk factors for breast cancer: the age (risk increases with age), country of birth (rates are highest in North america and northern Europe, and lowest in Asia and South america), and family history. Then adapt the imaging technology to the patient.

B) Digital Imaging: Space Technology Supporting Women's Health

For the past 5 years, NASA has worked with the National Cancer Institute (NCI) to apply the latest in advanced imaging technologies to the development of digital mammography systems, to yield the next generation of high-resolution, high-contrast digital mammography systems, which are expected to find smaller breast cancers.

C) Transferring Technologies from the Intelligence Community to the Medical Community

Scientists form the intelligence community (CIA), working in close collaboration with leading medical researchers, applied a neural network, modeled after human brain cells, (neurons) and developed to find targets in military surveillance images, to the problem of detecting microcalcifications in mammograms. Preliminary results generated by this joint team of scientists found that this neural network technology could be used to improve the accuracy of breast cancer detection by nearly a factor of two compared with the state-of-the-art computer-aided diagnosis (CAD) currently available in radiology.

D) Virtual Reality Applications in Women's Health

Advanced imaging technologies and three-dimensional (3-D) visualization are the cornerstone of virtual reality. As a medical application, virtual reality takes a previously acquired image from any method, such as a CT scan, MRI scan, or ultrasound, and uses a high-performance computer to create a full 3-D volume image. This 3-D image is now the "information equivalent" of the organ or tissue (such as the breast). Cancer Detection Using Interactive Computer Graphics.

In some cases, the military state-of-the-art technologies are more than a decade ahead of medical applications. An aggressive program to further catalyze cooperative efforts between defense investigators and the medical community is urgently needed if the Nation is to take advantage of these dual-use imaging technologies.

Conclusion

The Newer breast imaging techniques such as high resolution ultrasound imaging, MRI imaging, digital mammography, with the aid of computer analysis hold the promise of better cancer detection in the future. In the meantime because these technologies are not mainstream, patients should seek out breast imaging facilities with multimodal imaging capabilities, and which are actively involved in breast research: problem solving can then be tailored to individual. One should always remember that regular self-examination for women of any age along with periodic mammogram screening still offer the best hope for early detection, according to local health professionals.