

Radio-wave imaging: a new modality for breast imaging

By Dr Peter Bannister

Although X-ray based mammography is the most widely used technique for breast cancer screening and diagnostic imaging, the technology has several disadvantages, such as the risk of false negatives — especially in dense breasts — not to mention the use of ionizing radiation.

The imaging modality based on the use of radio-waves has the potential to overcome such drawbacks.

This article describes the basic principles of radio-wave imaging and summarizes the preliminary clinical results generated by a commercially available radio-wave breast imaging system.

Breast cancer is the most prevalent cancer in women, with approximately 1.7m new cases worldwide in 2012. It is the leading cause of death from cancer for women in many countries. According to the American Cancer Society, 2017 estimates, worldwide breast cancer causes over 500,000 deaths each year [1] with an estimated economic impact of \$88 billion each year. It is the most common cause of death in the EU for women aged between 35 and 55, with 1 in 8 contracting the disease in their lifetime. Around 80% of women will be the first in family to have been diagnosed with breast cancer. Since the 1970s, incidence has increased by 64% and in the UK is predicted to rise by a further 2% between 2014 and 2035 [2] where it is the most frequently occurring cancer in women with approximately 55,000 new cases diagnosed, and over 11,000 deaths in 2014.

The early diagnosis of breast cancer is of paramount importance, with a 5-year survival rate of 97% if the cancer is detected “locally”; This survival rate deteriorates to

79% if detected in the “axillary” lymph nodes, and to 23% if it has metastasised to the rest of the body. Unfortunately at diagnosis, most cancers are well established with a palpable tumor size. The surgical removal of small breast lesions (lumpectomy) is a straightforward, minimally invasive procedure, but a partial or full mastectomy is more complex, entails greater risk and results in considerable disfigurement, frequently requiring cosmetic surgery. Today 75% of patients diagnosed with breast cancer go on to have major surgical resection.

Apart from regular self-examination, the most important early detection system is provided by the numerous national asymptomatic breast screening programmes in place around the world. These are backed up by various follow-up diagnostic imaging and biopsy procedures for women whose screens have produced suspicious results.

Recent advances in screening and treatment have led to a decline in the mortality rate from breast cancer. Studies in Italy, the Netherlands, Sweden and the UK have demonstrated that screening programmes could reduce mortality by 22%. Analysis of survival rates in 16 European countries has concluded that improvement in mortality was due to both screening programmes and developments in treatment. However despite the encouraging decline in mortality, there are still issues with screening programmes. For example, the uptake of screening in the UK has fallen slightly since 2010/11. A study from 2013 demonstrated that up to 46% of women in England who did not re-attend the screening program cited pain associated with their previous mammogram as the main reason for their decision [3].

BREAST SCREENING PROGRAMMES

Screening programmes utilising x-ray mammography (XRM), were introduced in several countries in the 1980s. Today 10 countries of the European Union have a national screening programme in place. While the USA does not have a national screening programme, women are encouraged to have regular mammograms, reimbursed by health insurance. Evidence collected from screening programmes suggests that women between 50 and 69 years benefit from screening. The evidence is weaker for women between 40 and 49, due to technology limitations, although trials are ongoing in this population [4]. The predictive value of an abnormal mammogram increases with age, such predictive values being higher amongst women with a family history of breast cancer. The interval between screenings varies between countries. Most European countries with

The Author

Dr Peter Bannister

Chief Technology Officer,
Micrima Limited

Executive Chairman of the Institution of Engineering and Technology's
Healthcare Sector.

www.micrima.com

email info@micrima.com

screening programmes offer XRM every 2 years; 3 years in the UK. In the USA women are advised to have a mammogram every 1 to 2 years with shorter intervals for women under 50 due to more rapid cancer growth and poorer mammogram sensitivity, as a result of the low contrast between lesions and fibro-glandular or dense tissue exhibited by younger women and women of Far Eastern origin. Around 80% to 90% of abnormal screening mammograms are false positives. These require follow up testing and procedures such as breast biopsy, resulting in significant additional medical costs as well as anxiety, inconvenience and discomfort. Screening becomes more effective with the addition of other imaging modalities such as ultrasound or MRI. Together with invasive cytology or needle biopsy, these additions increase the accuracy to better than 90%. False negatives result in around 20% of cancers being missed, often in younger women with denser tissue. "Interval cancers" are those cancers that have become detectable since the last screening. Retrospective analysis of women who developed cancer after screening indicate that between 33% and 50% of lesions were, in fact, visible, but missed, on the initial mammogram. A recent study [5] reported XRM misses every other cancer in dense tissue, so whilst screening programmes are a positive activity they are still ineffective at finding cancer, particularly in dense tissue.

Diagnosis is currently achieved through clinical examination, imaging with XRM and/or ultrasound (US) and needle biopsy. XRM is dependent upon adequate breast compression to allow greater contrast differentiation between tissue structures, this is not only uncomfortable, but in younger women with dense breast tissue the contrast difference between normal tissue and tumor is minimal despite compression. Furthermore XRM uses ionising radiation, which means that a risk/benefit calculation is weighted against repeated or frequent use. Often it is necessary to use additional imaging such as ultrasound or MRI for diagnostic support.



FIGURE 1: The MARIA system, showing the Signal and Data Processing cabinet (containing the radiowave array) and patient bed. The patient lies with their breast pendulous through the hole in the bed, thereby avoiding the uncomfortable breast compression associated with XRM.

DIELECTRIC CONTRAST

Limitations of XRM have resulted in research into alternative methods for imaging of breasts with radio-wave detection of breast tumors being a potential non-ionising alternative [6]. Breast tumors have an additional attributes that can distinguish them from normal tissue which are defined by their dielectric properties. These includes two components – the dielectric constant (or relative permittivity), which affects the velocity of propagation of radio waves and therefore their wavelength, and the conductivity, which affects the rate of attenuation. Typically a tumor has a dielectric constant of 45-50 and a conductivity of 2S/m, whereas breast fat is 5-15 and 0.2-1S/m respectively but with considerable range. Normal glandular tissue falls between these two sets of ranges. The differences in dielectric constant can be exploited to aid breast cancer diagnosis. Initial results of radio-wave radar-based imaging have been presented [7-14] whose approaches rely on a difference in the dielectric properties of normal and malignant breast tissues [15-22] giving rise to varied changes to an applied radio-wave signal (which occupies the Ghz or "microwave" band). The breast as an organ is unique in the human body in that basic structure consists of glandular tissue (high dielectric

constant, high conductivity and is radio-opaque) in a fat-based matrix with low dielectric constant, low conductivity and relatively radio-lucent. Inclusions such as a tumor are also of high permittivity, enhanced by the angiogenic increase in vascularity; cysts contain fluid which also has very high permittivity.

RADIO-WAVE IMAGING

Radio waves are part of a spectrum that includes visible light. Just as with light, we can 'see' with radio beams: a radio antenna shines radio waves like a torch beam. Radio telescopes and RADAR use radio to make images: they focus the radio like a lens to create an image. A radio-wave imaging scanner works in a similar way – directing radio beams from antennas into the body and focusing the reflections to form an image. Most soft body tissues are more or less transparent to radio, so radio can shine into the body and create images of what is inside. The way in which radio waves pass through is related to the electrical property called impedance. Inside the body, changes in impedance reflect radio waves, so the image created from a radio-wave imaging scanner relates to the basic property of bio impedance. A radio-wave imaging array [Figure 2] works by focusing – in a very similar manner to how a lens focuses an image



Figure 2. The scanner consists of an array of radio antennas arranged around the inside of a hemispherical bowl. The array is located below a hole in the scanner bed and is covered by a round cup that fits the breast when the patient is in the prone position

in a camera, but also controlling the generation of the radio waves as well as receiving them. This is used to create an image in 3D rather than the conventional two.

A radio-wave scan shows reflections from objects inside the body. As with light, reflections happen at the surfaces of objects. So at its simplest, radio-wave imaging shows the surfaces of objects inside the body. Specifically, the brightness of the reflection is determined by the difference in bio impedance either side of the surface, so radio-wave imaging shows the change in impedance across a surface. Impedance describes how the tissue impedes the progress of radio waves leading to changes in their size and timing. The bio impedance is determined by a number of factors to do with the mix of tissue types – fat, tumor, water – and the details of each tissue’s water content. Bio impedance has been measured and analysed for more than 150 years. A body of evidence shows that tumors have a lower impedance than normal breast tissue: so the surface of a tumor embedded in normal tissue reflects radio-waves brightly and can be seen.

BREAST CANCER DETECTION WITH MARIA
Micrima’s MARIA (Multistatic Array processing for Radio-wave Image

Acquisition) radio-wave breast imaging system has a number of key advantages that make it ideally suited for the diagnosis and screening of breast cancer. Unlike XRM which is only accurate for women with lucent (fatty) breast tissue, MARIA is accurate in dense tissue typically associated with women below the age of 50. The technology is very low dose (exposure for a complete scan is equivalent to a few minutes mobile phone use), making repeated scanning safe, and the system is far more comfortable for the patient than XRM.

MARIA measures very different physical parameters to those exploited by XRM and is hence able to provide new diagnostic information. The scanner consists of an array of radio antennas arranged around the inside of a hemispherical bowl. The system uses a conformal array – designed to fit round the shape of the breast and with antennas that look at the breast from all sides in a closely packed pattern. The array is located below a hole in the scanner bed and is covered by a round cup that fits the breast when the patient lies face down. The scanner is operated by a radiographer, who is trained in carrying out imaging investigations. They control the scanner using a computer. Unlike an MRI or a mammogram, the radiographer is in the room with the patient during the procedure. The procedure is comfortable, painless and safe and takes just a few minutes

CLINICAL PERFORMANCE

MARIA has been used in the assessment of 86 women attending a symptomatic clinic in Bristol, UK in the so-called M4 study [2] and subsequently in a 227 patient multi-centre symptomatic trial in the UK (the M5 Study) [23,24,25]. The principal findings of these studies are:

- i) **M4 Study** – Pre-CE Mark evaluation on 86 patients, single centre trial in symptomatic breast clinics. Lesion detection sensitivity of 74%. A blind read of mammograms from 66 patients demonstrated MARIA found 12% of index lesions missed by XRM alone. [26]
- ii) **M5 Study** – Post-market study on 232

patients, 3 centre trial in symptomatic breast clinics. Lesion detection sensitivity of 77%, increasing to 84% for carcinoma in dense tissue and 100% (5 cases) for carcinoma in BI-RAD d (very dense) tissue. Blind read of first 30 cases using 4 independent readers demonstrated XRM found 90% of lesions and MARIA detected remaining 10%. [5]

FUTURE WORK

New studies centred around MARIA are due to commence at major EU centres and will consider several distinct groups of patients including symptomatic dense cases, high risk (BRCA1/2 screening) and women receiving neoadjuvant chemotherapy who can be safely and comfortably imaged across therapeutic intervals of only a few weeks. MARIA is also demonstrating an increasingly accurate ability to automatically identify the type of lesion being imaged based on the inherent radio-wave “signature” of targets [8] and also provide direct measurements of local breast density [9].

CONCLUSION

This diagnostic modality could prove to be a major step forwards in cancer detection, initially as a complementary source of information that can increase confidence in results obtained from established technologies that are routinely deployed in the clinic.

MARIA also has the potential to make safe and effective screening available to women from a younger age, due to the absence of ionising radiation and unlike XRM not being limited by ‘dense’ tissue, enabling the application of current clinical interventions that are known to lead to overwhelmingly positive 5-year outcomes when the tumor is less than 10mm in diameter [7].

MARIA at RSNA 2017

Oral Paper: SST01-08 A reader study of MARIA radio-wave breast imaging compared with x-ray mammography for the symptomatic breast
Date and Time: 12/1/17, 11:40 AM - 11:50 AM

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Book Review

MRI-Essentials.com: a textbook of orthopedic MRI. Second edition

by Fischer, Guermazi, Roemer, Carrino, Crema, Grainger, Kijowski & Steinbach

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MRI-Essentials.com covers all aspects of musculoskeletal MRI with an emphasis on orthopedics and sports medicine. The text is highly compressed and enhanced by more than 4000 MR images of outstanding quality. Examples of some complex pathologies are included, but without straying from the subject. Learning in radiology, like all learning, is a combination of knowledge acquired from those around

us, knowing the science and personal experience. Presentation and analysis of actual MR images is of fundamental importance to such personal experience beyond the daily exposition of cases. The images included in this book were chosen to provide the opportunity for such analysis, but the most important criterion for their use was that the images be relevant to clinical practice.

MRI-Essentials.com can be studied and read from the beginning to the end to gain a deeper insight into musculoskeletal MR imaging, but it can also be dipped into for information on specific topics. Basic knowledge of MRI is helpful to take full advantage of its content. The structure of the book is as logical as possible to allow easy access to its contents so that it can be of use in daily radiology practice. Finally, any non-radiologists involved in the diagnosis and treatment of orthopedic conditions will profit from this book, as knowledge of MRI is always important for communication and decisions about treatment.

Compared to the 1st edition, the 2nd has grown by 70 pages, 750 images and a large number of literature references. During the revision, the authors constantly asked themselves whether this expansion was justified. On the one hand, they wanted to offer the reader as much as possible and provide all relevant information. On the other hand, the claim of this book is to be short and concise, and to be reduced to the clinically relevant facts.

The 2nd edition is a good compromise between these difficult and conflicting objectives and promises to be a valuable tool in daily radiological work.

The book is available at www.mri-essentials.com

